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REPORT OF SURVEY CONDUCTED AT

**ELECTRIC BOAT CORPORATION,
QUONSET POINT FACILITY
NORTH KINGSTOWN, RI**

MARCH 1999



Best Manufacturing Practices

1998 Award Winner



INNOVATIONS IN AMERICAN GOVERNMENT

BEST MANUFACTURING PRACTICES CENTER OF EXCELLENCE
College Park, Maryland
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Foreword



This report was produced by the Office of Naval Research's Best Manufacturing Practices (BMP) program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective toward this goal is simple: to identify best practices, document them, and then encourage industry and government to share information about them.

The BMP program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management – all areas which are highlighted in the Department of Defense's 4245.7-M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource in helping companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to learn from others' attempts and to avoid costly and time-consuming duplication.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at Electric Boat Corporation, Quonset Point Facility (EBQP), North Kingstown, Rhode Island conducted during the week of March 22, 1999. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from industry, government, and academia throughout the U.S. and Canada – *so the knowledge can be shared*. BMP also distributes this information through several interactive services which include CD-ROMs, BMPnet, and a World Wide Web Home Page located on the Internet at <http://www.bmpcoe.org>. The actual exchange of detailed data is between companies at their discretion.

Built on a proud heritage, Electric Boat's experience, technical expertise, and dedication to continued improvement have provided the U.S. Navy with a submarine force that is second to none. The company is ensuring that today's ships can be enhanced by tomorrow's technology at a price that America can afford. Among the best examples were EBQP's accomplishments in employee assistance program; process improvement program; safety quality action team and safety action reviews; cost of quality program; off-hull outfitting; automated frame and cylinder system; and barging from Quonset Point to Groton.

The Best Manufacturing Practices program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this one on EBQP expand BMP's contribution toward its goal of a stronger, more competitive, globally-minded, and environmentally-conscious American industrial program.

I encourage your participation and use of this unique resource.

A handwritten signature in cursive script, reading "Ernie Renner".

Ernie Renner
Director, Best Manufacturing Practices

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Section 1

Report Summary

Background

John Phillip Holland was an Irish schoolteacher who dreamed of perfecting the submarine boat. Backed by various financial sources (e.g., Irish Fenian Brotherhood, U.S. government-sponsored contests, Holland Torpedo Boat Company), he made five unsuccessful attempts between 1876 and 1896. Despite these setbacks, he victoriously launched the *Holland VI* on May 17, 1897. This 54-foot submersible vessel was powered on the surface by a 50-horsepower engine and by electric batteries when submerged. A major advancement in submarine design, the *Holland VI* featured dual propulsion systems, a fixed longitudinal center of gravity, separate main and auxiliary ballast systems, a hydrodynamically advanced shape, a modern weapons system, and the ability to recharge its battery and compressed air reservoirs without returning to port. However, an examination by the Navy Board of Inspection and Survey revealed that the vessel was sluggish and difficult to control.

Isaac Rice was a lawyer and a financier who also had a dream. By 1898, he had secured a virtual monopoly in the storage-battery business and began acquiring companies that used them. After touring the *Holland VI*, Rice agreed to finance the necessary modifications. In 1899, he consolidated several of his holdings, including those in the Holland Torpedo Boat Company, and set up the Electric Boat Company. The following year, the world's first practical submarine was commissioned into the Navy as the *U.S.S. Holland* (SS-1). Today, Electric Boat Corporation operates as part of General Dynamics, and has sister subsidiaries that build surface combatants and auxiliary ships. The company also works on the design of next-generation aircraft carriers and amphibious ships, and continues to make advancements in submarines at its Groton, Connecticut and Quonset Point, Rhode Island facilities.

The BMP survey focused on the Electric Boat Corporation, Quonset Point Facility (EBQP) in North Kingstown, Rhode Island. In the early 1970s, Electric Boat was considering a major expansion of its capabilities and facilities to accommodate the simultaneous construction of the Los Angeles-class and Trident submarines. Coincidentally, the State of Rhode Island was seeking tenants for its recently closed

Quonset Point Naval Air Station. Ten days after EBQP's official November 23, 1973 opening, eight trainees and a handful of managers worked as jacks-of-all-trades to bring the production facility into operation. This 169-acre facility rapidly grew to 5,700 employees, underwent massive downsizing in the early 1990s, and is currently rebuilding at 1,500. Located on the Narragansett Bay, EBQP has ready access to water, air, rail, and interstate highway systems.

The basic construction of Electric Boat submarines takes place at EBQP. The facility's unique fabrication capabilities can produce submarine hull cylinders up to 42 feet in diameter, using a fraction of the personnel once required to form a traditional hull. Major submarine components are manufactured using digitally-controlled machines for cutting, machining, and bending. This precision process is driven by the digital design data transmitted via computer from the Groton facility. The completed submarine hull cylinders are outfitted with tanks, propulsion and auxiliary machinery, cruise missile and torpedo tubes, piping, wiring, and lighting — then barged to Connecticut (Electric Boat) or Virginia (Newport News Shipbuilding) for completion. Among the best practices documented were EBQP's employee assistance program; process improvement program; safety quality action team and safety action reviews; cost of quality program; off-hull outfitting; automated frame and cylinder system; and barging from Quonset Point to Groton.

For a century, Electric Boat has been in the forefront of submarine technological development and innovation. Noteworthy accomplishments include the *U.S.S. Cuttlefish* (SS-171), the first welded submarine; the *U.S.S. Nautilus* (SSN-571), the first nuclear powered submarine; and the *U.S.S. George Washington* (SSBN-598), the first fleet ballistic missile submarine. With the upcoming construction of the Virginia-class new attack submarines, the *U.S.S. Virginia* (SSN-774) will be the first major warship designed entirely by computer. Built on a proud heritage, the company's experience, technical expertise, and dedication to continued improvement have provided the Navy with a submarine force that is second to none. Electric Boat is ensuring that today's ships can be enhanced by tomorrow's technology at a price that America can afford. The BMP survey team considers the following practices to be among the best in industry and government.

Best Practices

The following best practices were documented at EBQP:

Item	Page	Item	Page
Accuracy Control and Photogrammetry	9	Elimination of Seams by Maximization of 360° Forming	11
EBQP developed the Accuracy Control and Photogrammetry program to support a modular approach to submarine construction. This practice involves measuring selected dimensions during the manufacture, assembly, and outfitting stages to allow in-process adjustments. As a result, the final product meets the drawing requirements, readily fits mated parts, and achieves system functional needs.		EBQP developed new tooling and techniques so that heavy-walled 360° cylinders could be manufactured from a single piece of material. The process involves manufacturing special window dies so that the material can be press-formed into a cylinder. As a result, only one weld is necessary to complete the part.	
Automated Frame and Cylinder System	9	Fabrication and Installation of Electrical Hangers	11
A key element in building high quality, cost effective submarines is the fabrication and assembly of pressure hull frames and cylinders. In 1979, EBQP along with a Swiss firm developed the Automated Frame and Cylinder system to fabricate and assemble these components.		EBQP developed detailed work instructions to simplify the fabrication and installation of electrical hangers. The company uses a CATIA product model to generate the detailed work instructions. These instructions provide a precise drawing that shows the configuration and exact location for each electrical hanger.	
Barging from Quonset Point to Groton	10	Implementation of Cold Form in Lieu of Hot Form	12
In the early 1980s, Electric Boat Corporation upgraded its transportation capabilities by purchasing a Sea Shuttle Jack-Up Barge and modifying its Quonset Point and Groton facilities for compatibility. In conjunction with the barge, Electric Boat purchased two Scheuerle transporters, each with a 790-ton capacity, for drive-on capabilities.		Hot forming techniques can be an expensive and cumbersome process for manufacturing complex metal parts. Searching for a more economical and faster way to produce these parts, EBQP developed cold forming techniques using existing equipment.	
Electronic Record System	10	Improved Quality and Flatness of Deck Assemblies	12
EBQP developed the Shipyard Weld Status System to capture the completion of weld joint work and provide assurance of weld accountability per the Navy's SUBSAFE requirements. In 1998, the company enhanced this system by setting up the Electronic Record System which was implemented for the Virginia-class submarines. The Electronic Record System is a series of operator/computer interaction.		Previously, EBQP used multiple shop groups led by different foremen to assemble a submarine deck structure. Each group defined its own procedures and sequencing for assembly which led to varying results. In 1997, the company resolved these issues by optimizing and standardizing the assembly sequence for its deck structures.	
Electronic Visualization Simulation	11	Manufacture of Hangers	13
Since 1992, Electric Boat's Groton facility has been using Electronic Visualization Simulation as a tool for design and production engineers. With support from Groton, EBQP recently implemented this tool to simulate its block fabrication and assembly process. This state-of-the-art package visually shows the sequential steps of the assembly process, provides zoom capability for greater detail, and adjusts the simulation when the sequence/process parameters are changed.		In 1994, EBQP developed a Hanger Fabrication Shop to ensure that all hangers are fabricated in a timely and economical manner. The Shop features six specialized work areas (kit; prep; fit; weld; blast and powder paint; final assembly) and uses employees who are cross trained in the operations of each area.	
		Manufacturing Resource Planning Metrics	13
		In 1989, EBQP purchased the Manufacturing Resource Planning II system and modified it to meet the specific needs of the facility. This system controls cost by providing the company with management information and work scheduling system capabilities.	

Item	Page	Item	Page
Mini Crib System	13	Super Piece Mark Process	17
EBQP incorporated a Mini Crib system into its operations to reduce the amount of time that employees spent on obtaining consumables and tools for their work assignments. To implement the new approach, EBQP prestocks the mini cribs at the main crib and then moves them to the individual work centers.		The Super Piece Mark process enables EBQP to create a part from raw flat plate that is welded together. The process minimizes irregular fit-ups and weld shrinkage; improves the dimensional accuracy of parts; and reduces stack-up tolerances due to as-built conditions.	
Modular Construction and End Loading	14	Trade Interface Program	18
Over the years, Electric Boat Corporation changed its submarine manufacturing practices from an on-hull construction process to an off-hull (modular) construction process. By switching to a modular construction approach, EBQP performs most of its shipbuilding processes in a controlled shop environment with improved accessibility and system testing capabilities.		On any particular day at EBQP, up to 100 tradespeople are involved in the construction, assembly, and installation of a hull section. To coordinate trade interfacing and ensure the prioritization of prerequisite sequence issues, the company developed the Trade Interface Program.	
Multi-Trade Program	15	Welding Quality Accountability	18
In 1990, EBQP initiated the Multi-Trade program to improve its modular construction process and foster a flexible workforce. Through this program, trade workers are offered extensive training in alternative trades including shipfitting, welding, piping, mechanical, ventilation, electrical, and sound damping. The goal of the program is to train workers in three trades outside their specialty.		In the late 1970s, EB Groton developed the Shipyard Weld Status System to provide quality accountability for the structural welds of submarines. Approximately ten years later, the company developed the Automated Weld Process Selection System which was tied into the previous system as well as the Personnel Qualification System. Now, supervisors can easily locate information pertaining to welder qualifications and welding specifications.	
Nesting Process for Steel Plate and Sheet Metal	16	Energy Management System	19
In 1989, EBQP improved its steel plate and sheet metal practices by implementing a computerized Nesting process. This process differs from other software programs because it requires minimal staff to operate and possesses a high level of automated electronic integration into EBQP's Manufacturing Resource Planning II system.		EBQP implemented an Energy Management System to regulate various processes and operations (e.g., air compressors; steam valves; heating, ventilation, and air conditioning; argon; electricity) throughout the company. The system performs two major functions: (1) constantly monitors critical facility operations via sensors and (2) controlling standard on/off processes so output is proportional to demand.	
Nuclear Pipe Shop	16	Automated On-Line Personal Protective Equipment and Restriction Certification	20
EBQP set up its Nuclear Pipe Shop as a controlled area with restricted access, a strong organizational structure, and the ability to maintain system cleanliness. These attributes, in conjunction with the knowledge and experience of the employees, foster the shop's high level of quality and precision in manufacturing nuclear products.		In 1998, EBQP upgraded its Automated Time & Attendance system to provide easy notification and accessibility regarding physical work restrictions. This system also handles personal protective equipment requirements and training per Occupational Safety and Health Administration regulations.	
Pipe Marking, Cutting, and Bending	17	Community Outreach: School to Career Program	20
EBQP automated its pipe marking, cutting, and bending processes by implementing Direct Numerical Control and Computer Numerical Control systems. In the past, most operations were done manually.		In 1996, EBQP initiated the Community Outreach: School to Career program as a way of becoming an active participant and recruiter in the local community. Through this program,	

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EBQP participates in high school career and science fairs; maintains active contact of recent graduates via school superintendents; participates in Chamber of Commerce events; and offers facility tours for local students.		teamwork environment; educate/train for promotional opportunities; emphasize safety; reduce production costs; and develop employees with overall job satisfaction.	
Cost of Quality Program	21	Facility-Wide Communication Program	23
Quality cannot be compromised when building the most capable and safest nuclear submarines that industry can produce. In 1998, EBQP initiated the Cost of Quality program which measures overall performance as it relates to quality. The program is based on a matrix of 22 elements (e.g., structural radiography welding rejections, braze rejections, test inspection reports, customer concerns, out of tolerance reports, magnetic particle rejections), which represent the major quality indicators for the facility.		EBQP recognizes communications as an important tool for clearly disseminating announcements, updates, policies, and procedures throughout the facility. The Facility-Wide Communication program is a gradual process, but utilizes some low technology and innovative methods for security, safety, and general issues.	
Diversity Group	21	Flat Organizational Structure	24
EBQP set up the Diversity Group as a way to foster cultural and employee relations. The Diversity Group teaches employees how to interact with one another, acknowledge cultural differences, and treat everyone with respect. By educating the workforce on diversity issues and topics, the Group strives to achieve an environment that attracts, develops, and retains the most qualified employees at every level of the corporation.		Prior to 1992, the organizational structure of EBQP's fabrication and assembly operations consisted of seven layers of management. Today, the company uses only three layers of management (Site Manager, Superintendent, and First Line Supervisor) for its operations. This arrangement increased the supervisory ratio to nearly 15:1, and reduced overhead and indirect labor costs by more than 50%.	
Employee Assistance Program	22	Industrial Safety Program	24
EBQP provides a comprehensive employee assistance program, known as Optum Care 24, for its employees and their dependents. This program addresses all aspects of health and well being; provides accessibility to information and resources for almost any problem; and is administered as part of EBQP's employee healthcare plan.		EBQP set up its Industrial Safety program as a managed system of safety policies, procedures, and training. The program was developed to minimize hazards in the workplace; lower the employee injury rate; reduce Workers' Compensation claims; and help employees quickly identify and correct conditions that may occur in a dynamic work environment.	
Employee Community Services Association	22	Leadership Development and Supervisory Skills Training	25
EBQP established the Employee Community Services Association as an outreach program to help employees and the community. The program operates as a non-profit organization, and oversees the collection and distribution of donated funds from the workforce to organizations such as the United Way, Requested Assistance, and Catastrophic Needs.		EBQP has a long-standing commitment to personal development for its workforce, supervisors, and management. After the massive downsizing of the early 1990s, the company began revising its management development practices. Today, EBQP requires all levels of management to complete leadership development and supervisory skills training.	
Entry Level Mentor Program	22	Process Improvement Program	25
After the massive downsizing of the early 1990s, EBQP decided to reinvent its hiring process by setting up the Entry Level Mentor program. The goals of this program are to improve the skill mix; establish a diverse, flexible workforce; provide a		Process improvements are often small changes that put employees' ideas into action and result in enrichment for the company. Seeking a more effective way to capitalize on process improvements, EBQP developed the Process Improvement Program in November 1997. This comprehensive and integrated program focuses on the capabilities, experience, and ideas of the workforce for implementing process improvements.	

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Recognition Programs	26

EBQP considers employee recognition as the fuel of ongoing motivation, and has developed an extensive list of effective programs. These programs are designed to be fast, flexible, easily implemented, and applicable to a large portion of the workforce.

Safety Quality Action Team and Safety Action Reviews	27
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In 1992, EBQP established the Safety Quality Action Team which has been instrumental in setting up many safety policies and upgrades including safety recognition, eye safety, and burn prevention. In conjunction with the team's efforts, the Safety Department holds weekly Safety Action Reviews to evaluate injuries that occurred during the previous week.

Security Badge System and Clearance Monitoring	27
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National security is an important aspect at EBQP due to the nature of its business. Great care must be taken in classifying and monitoring clearance levels, and in issuing security badges to employees, vendors, and visitors at the facility. Recently, the company upgraded its Employee Badge Control System and Monitoring process to work as a stand-alone process with a minimal number of authorized users.

Simultaneous Machine Shop Operations Program	28
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In February 1998, EBQP implemented a Simultaneous Machine Shop Operations program as a cost-reduction measure for its Machine Shop. Simultaneous operations is defined as two machines engaged concurrently in either an operating/operating mode or a set-up/operating mode. As an incentive, a special pay provision is awarded to employees who run concurrent machines.

Van Pool Program	28
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In 1980, EBQP implemented Quonsetrans, a Van Pool program for its employees. Electric Boat Corporation administers this program as a non-profit effort with usage fees paid by the ridership; provides insurance at corporate rates which significantly reduces operational costs; and purchases vans by utilizing the Federal Highway Administration's interest-free loans.

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Work-In-Process Management	29

In 1995, EBQP developed the Work-In-Process Management approach for handling its in-process inventory. To implement this approach, EBQP modified its Manufacturing Resource Planning II system to ensure that each part's routing sheet clearly displays a destination point-of-use. This information can be changed dynamically, based on real-time workload conditions, which reduces the cost of maintaining inventory.

Information

The following information items were documented at EBQP:

Item	Page
Automated Tool Inventory Control Tracking System	31

In 1986, EBQP implemented the Automated Tooling Inventory Control Tracking System which tracks and controls consumable items such as welding inserts, wire, and critical tooling. In addition, this off-the-shelf software package has been enhanced and linked to EBQP's Automated Weld Process Selection System, so only qualified, authorized personnel can obtain an item from the system.

Calibration Program	31
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In 1992, EBQP implemented the Calibration program as a way to ensure that all tools requiring calibration were sent to the Metrology Laboratory on or before their due date. As a result, the company increased customer satisfaction by preventing any out-of-date calibrated tools from being used for process measurement.

Computer Numerical Control Manufacturing Capabilities	31
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EBQP utilizes a wide variety of manual and state-of-the-art Computer Numerical Control machine tools throughout its facility. These tools are used to perform many of the manufacturing processes in the Machine and Sheet Metal Shops.

Construction Activities Supported by Deckplate Design-Build Teams	32
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Seeking a way to resolve design-production manufacturing issues associated with the Virginia-class submarines, EBQP set up Deckplate Design-Build Teams. These teams support current and

Item	Page	Item	Page
near-term construction activities, and typically resolve design-build problems in four days compared to 23 days for the previous submarine class.		ing geometry and reducing paper processing times. The program is also fully integrated into EBQP's Manufacturing Resource Planning II system.	
Cut Neat Program in Structural Areas	32	Powder Paint	34
As more of the shipbuilding industry is moving toward modular construction for ship assembly, focus has shifted to the delivery of accurate, ready-to-install, cost effective piece parts. One of the ways that EBQP is responding to this need is by implementing the Cut Neat program in structural areas.		EBQP extensively uses an electrostatic powder paint spray coating on small structural steel items (up to 68 pounds), followed by an elevated temperature cure cycle. This process contributes to the company's efforts of being an environmentally compliant manufacturing facility.	
Electrical Component Installation	32	Release to Weld Process	35
Electrical component installation of Seawolf-class submarines involves 158 electrical systems and more than 6,500 components. To handle this workload, EBQP utilizes modular construction and completes most electrical component installation prior to final assembly.		EBQP has been using the Release to Weld process since the mid-1980s. Through this process, sizeable welding jobs are only released to the welders when large sections of a deck assembly or tank are fit-up, tacked, and ready for joining. Since the fit-up on these sections is complete, the welder can begin work immediately and continue uninterrupted for days or weeks depending on the job size.	
Flexible Workforce	33	Ultrasonic and Radiography Welding Program	35
EBQP's structural fabrication workforce consists of two core trades: welders and shipfitters. Those skilled in both trades are considered members of the flexible workforce. To be eligible for the flexible workforce, tradespeople must be at the top rate of their own trade and complete 200 hours in the other trade under the observation of a foreman.		During the construction of submarine subassemblies at EBQP, numerous structural weld joints require ultrasonic and radiographic testing to confirm specification-required acceptance weld quality. The company uses a team of structural welders known as the Ultrasonic and Radiography Team to maintain the high degree of quality for these critical welds. This approach has worked extremely well at EBQP as quality performance data shows a rejection rate of less than 1% for all ultrasonic and radiographic testing structural welds.	
Lift and Handling Crane Program	33	Welding Procedures and Processes	35
EBQP set up a Lift and Handling Crane program as a formalized process to document maintenance procedures for its cranes. This program led to other initiatives such as a Crane Inspection Training program; an Engineered Managed Program; a Crane Quality Manual; a Repair, Maintenance, and Modification Report program; a Record-keeping and Filing System; and a Quality Assurance Engineering program.		EBQP uses a wide range of welding procedures, methods, and base materials to meet its production requirements. The large number of processes and materials requires almost 1,000 different welding technique sheets and procedures. To determine which of its 229 structural and 54 pipe welders are certified for a particular job, supervisors use EBQP's Automated Welder Process Selection System.	
On-Board Machining	33	Environmental Resources Management	36
EBQP has developed and applied many processes and procedures for on-board machining of large fabrications (e.g., deck units, hull structures) used in ship construction. In some cases, surface requirements for size, finish, and tolerance can only be done after the units are welded together and machined in place. As a result, on-hull machining becomes a major part of the fabrication process.		EBQP is proactive in all aspects of environmental resource management. All employees receive pollution prevention training with the overall message of Environmental Management Is Everyone's Responsibility. In that regard, the company is satisfying existing compliance requirements and addressing potential long-term liability issues.	
Pipe Shop Process	34		
EBQP's Pipe Shop process uses electronic systems for generating and managing the status of pipe operations, thereby improving the accuracy of pip-			

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Complaint Procedure and Open Door Policy	36	Critical Skills Database	37
EBQP developed the Complaint Procedure and the Open Door Policy as two alternative processes (formal and informal, respectively) for resolving complaints. Each process supports the company's philosophy of an open dialogue between employees and management within an environment of cooperation and respect in the workplace. Employees may utilize one process or the other, but not both.		EBQP has developed a Critical Skills Database which will be implemented on October 1, 1999. The database will identify and track critical skills, as required by the different trades for nuclear and non-nuclear applications, and will list which employees have been trained in these skills.	
Computer-Based Training	37	<i>Point of Contact</i>	
Based on a long recognized need to make refresher training available to shop floor and office personnel, EBQP is currently implementing two computer-based learning tools. One involves CD-ROM technology and the other uses web-based technology.		For further information on items in this report, please contact:	
		Mr. Richard Nelson, Jr. Electric Boat Corporation 75 Eastern Point Road Groton, Connecticut 06340-4989 Phone: (860) 433-2000 Fax: (860) 433-7776 E-mail: rnelson@ebmail.gdeb.com Web: http://www.gdeb.com	

Section 2

Best Practices

Production

Accuracy Control and Photogrammetry

In the past, the Electric Boat Corporation, Quonset Point Facility (EBQP) assembled submarine hulls as empty shells. Internal structures and components were built per plan by shipyard trades; loaded into the assembled hull through access holes cut into the top/side of the shell; and positioned using a common grid system. These assembly practices were inefficient and time consuming, and required extensive support by measurement personnel. As a result, assembly conditions were often accepted based on individual interpretation of the plan requirements. Most work was done sequentially and took more than five years to complete a start-to-finish cycle (keel laying to product delivery). In addition, off-hull fabrication was built to final plan tolerances, which left no leeway for installation in the submarine.

EBQP developed the Accuracy Control and Photogrammetry program to support a modular approach to submarine construction. This practice involves measuring selected dimensions during the manufacture, assembly, and outfitting stages to allow in-process adjustments. As a result, the final product meets the drawing requirements, readily fits mated parts, and achieves system functional needs. Key elements of the Accuracy Control program include identifying critical requirements (e.g., SUBSAFE and key ship specifications, critical systems alignments and tight tolerances, modular construction requirements, machining of structure prior to assembly or installation), developing an electronic database for these requirements, creating 3-D computer aided design (CAD) models, budgeting tolerance levels, and providing accuracy control training.

By using accuracy control procedures, EBQP can place heavy emphasis on the dimensional control of components and structures to ensure proper fit-ups at all phases of assembly including the use of sophisticated photogrammetry systems to accurately measure complex curved and spherical assemblies (e.g., hulls, sonar spheres). Dimensional data is easily gathered and evaluated. Any out-of-tolerance conditions are immediately reported and reviewed to identify the cause, determine immediate corrective actions, and define future corrective actions.

The Accuracy Control program has been instrumental in the success of EBQP's modular construction of submarines. Since implementing this proactive program, the company improved product delivery time and reduced its construction schedule from five years to four. Work is now performed in parallel, and hull sections are almost completely outfitted prior to joining to form the completed ship. Most fabrication is accomplished off-hull or in open-ended hull sections for better accessibility, thereby eliminating trial pairings and the need for extra stock on many items. The Accuracy Control program also produced significant savings in labor hours for the Los Angeles-class and Trident submarines: 64% and 35% for sectional hull butts, and 23% and 32% for frame and cylinder manufacturing for these classes respectively.

Automated Frame and Cylinder System

A key element in building high quality, cost effective submarines is the fabrication and assembly of pressure hull frames and cylinders. In the past, EBQP fabricated these components by leaving excess stock on the piece parts, then cutting and grinding them to fit at assembly. Each assembly required custom spider fixtures, temporary attachments, spacers, and numerous hydraulic jacks. If any operation involved turning a component, then a 10- to 15-person rigging crew was also needed. Overall, this method was costly, schedule and labor intensive, and required great effort to meet the desired quality. In 1979, EBQP along with a Swiss firm developed the Automated Frame and Cylinder (AFC) system to fabricate and assemble these components.

The AFC system consists of four, mechanized fixture types (A, B, C, D) and associated support equipment. A-fixtures are designed for manufacturing the frames; B-fixtures are designed for manufacturing the shell or cylinders; C-fixtures are designed for assembling the frame and cylinders; and D-fixtures are designed for mating two frame and cylinder assemblies. All fixtures can be adjusted to accommodate cylinder and frame diameters from approximately 32 feet to 42 feet.

Each fixture works similarly. The fixture is first configured for the part being fabricated by using a setup sheet supplied by Engineering. Next, the fixture is loaded with piece parts already burned to final size.

Held in place by the actuation of hydraulic clamping systems, these parts are tack welded and dimensionally checked. Once the dimensional results are accepted, the assembly can be welded. The fixture contains all utilities (e.g., lights, preheaters, power) and support equipment (e.g., elevators, work platforms), and can handle multiple welding options such as mechanized, semi-automatic, and automatic versions of gas metal arc-pulsed, submerged arc welding, and shielded metal arc welding. The fixtures also include provisions to easily turn parts which allows for improved weld and working positions.

The AFC system enabled EBQP to reduce its production times by more than 70% in some cases. As a result, the company significantly decreased cost, improved scheduling, and increased the dimensional quality of all associated parts.

Barging from Quonset Point to Groton

In 1974, EBQP began fabricating small steel components (e.g., internal submarine tanks) and shipping them to the Electric Boat facility in Groton, Connecticut for assembly. Initially, the components were sent via trucks or small barges. As its capabilities increased, EBQP started manufacturing internal submarine components as well as larger units such as hull sections. To reduce manufacturing costs at Quonset Point and alleviate limited assembly space at Groton, EBQP planned to outfit the hull sections with internal structures and hardware prior to shipping them. However, the existing crane and barge capabilities (300 metric tons) at the company were insufficient to handle the weight of outfitted hull sections. The answer was to upgrade the transportation capabilities.

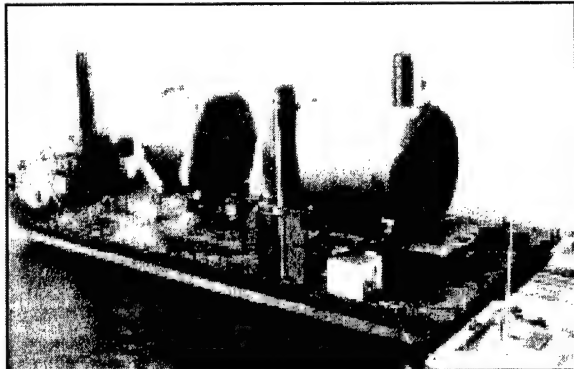


Figure 2-1. Sea Shuttle Jack-Up Barge

In the early 1980s, Electric Boat Corporation acquired a Sea Shuttle Jack-Up Barge (Figure 2-1) and modified its Quonset Point and Groton facilities for compatibility. This 75 x 195-foot barge has a dead

weight capacity of 2,200 tons and features drive-on capabilities for loading and unloading. To stabilize itself, the barge extends its three legs into the water and onto a concrete pad at the dock. The legs also lift the barge out of the water until the deck is level with the dock. In conjunction with the barge, Electric Boat purchased two Scheuerle transporters, each with a 790-ton capacity, for drive-on capabilities. These transporters can also be used in tandem to move up to 1,580 tons onto the barge.

Recently, EBQP teamed with Newport News Shipbuilding (NNS) to jointly build the Virginia-class new attack submarines. Under this arrangement, each shipyard takes the lead on constructing certain sections of the submarine, and both facilities will share the final assembly responsibilities. Since large sections will need to be shipped between their sites, EBQP and NNS developed a transportation plan based on Electric Boat Corporation's technique for shipping from Quonset Point to Groton. To implement this plan, NNS is constructing a docking facility and EBQP is upgrading the Sea Shuttle Jack-Up Barge to U.S. Coast Guard standards for ocean use.

EBQP realized many benefits from implementing the Sea Shuttle Jack-Up Barge and the Scheuerle transporters. This transportation approach increased size and weight capacities, simplified loading and unloading procedures, and reduced the number of trips made by the barge. By being able to transport outfitted hull sections to another site, EBQP also shortened its production cycle and realized significant cost savings. The ability to outfit hull sections prior to assembly is a major benefit, which typically reduces expenses to the cost of on-ship outfitting.

Electronic Record System

EBQP developed the Shipyard Weld Status System (SWSS) to capture the completion of weld joint work and provide assurance of weld accountability per the Navy's SUBSAFE requirements. In 1998, the company enhanced SWSS by setting up the Electronic Record System which was implemented for the Virginia-class submarines. Previously, SWSS relied on hard copies for maintaining records. Weld joint information (e.g., base material and thickness; preheat/interpass temperatures; non-destructive testing [NDT] requirements; inspections) was either downloaded from design tapes or manually loaded to the SWSS database, and a card was printed so employees could sign-off on completed activities. The database was manually updated based on the information on a card, and each hull required approximately 300,000 cards.

Quality Assurance retained these cards until the hull was delivered and then sent them to a storage facility.

The Electronic Record System is a series of operator/computer interaction. As data is downloaded to the SWSS database, it goes through a logic phase. This phase establishes a routing path of activities based on NDT requirements. A typical routing path would be: fit, backgouge, weld, inspection, review. The trade foreman assigns an employee to each activity. Employees are responsible for updating the Electronic Record System after completing an activity. To do this, employees scan their security badges through a magnetic strip reader to gain access to the system; enter the new information; and re-scan their badges as confirmation. The Electronic Record System can also query the Personnel Qualification System to determine whether an employee is qualified to sign-off on a particular activity. Other functions of the system include monitoring activities for ship progress/completion, time charging, and attendance purposes.

By using an electronic method for maintaining records, EBQP realized significant cost savings. The Electronic Record System enables employees to electronically sign-off on a routing activity; prevents activities from being done out of sequence; and checks the qualification of the employee signing-off on an activity. In addition, the system logically checks the NDT time delays which prevents an inspector from signing-off on work before the proper due date.

Electronic Visualization Simulation

Since 1992, Electric Boat's Groton facility has been using Electronic Visualization Simulation (EVS) as a tool for design and production engineers. With support from Groton, EBQP recently implemented EVS to simulate its block fabrication and assembly process. This state-of-the-art package visually shows the sequential steps of the assembly process, provides zoom capability for greater detail, and adjusts the simulation when the sequence/process parameters are changed.

Skilled trade workers view the 3-D visualizations generated by EVS. This approach enables them to see the construction sequence of complex assemblies prior to production release; identify potential difficulties in the construction process; and make suggestions for improvement. In addition to the simulations, EBQP uses still photographs to record each step of the construction process and to analyze possible process improvements. The photographs are also used to plan the construction of subsequent submarines, which aid trade workers who may not have been involved

with earlier constructions. EVS is based on IGRIP software (Deneb Corporation), and the actual product model data is derived from the CATIA design database.

Since implementing EVS, EBQP significantly improved its production process. The EVS sessions offer an effective way to visualize the sequential steps; promote ownership of the fabrication process; and provide a forum to discuss improvements (e.g., reduce cost, improve quality, decrease delivery time).

Elimination of Seams by Maximization of 360° Forming

EBQP developed new tooling and techniques so that heavy-walled 360° cylinders could be manufactured from a single piece of material. In the past, these cylinders were formed by welding two 180° segments together. The process involved prepping segment edges, making four bevels, welding two seams, and then inspecting the seams. The use of two segments was more expensive than one piece because excess material was needed on all edges to allow for prebending. Aligning the segments was difficult and often created excessive root gaps, which led to additional welding and liberal use of tolerances to make parts acceptable.

By manufacturing a part from a single piece of material, EBQP maximized the 360° forming process. The process involves manufacturing special window dies so that the material can be press-formed into a cylinder. As a result, only one weld is necessary to complete the part. EBQP's design and manufacturing engineers are also working together to identify other parts which can be formed from a single piece.

By maximizing the 360° forming process, EBQP improved the dimensional quality (e.g., circularity, verticality, girths) of its cylinders. This approach also decreased costs by eliminating extra stock for prebends and reducing edge preparations, fit-ups, weld joints, and weld volume.

Fabrication and Installation of Electrical Hangers

In the past, fabricating and installing electrical hangers were time-consuming tasks. Skilled trade workers were given a drawing of the cable run, and told a specific point on the run to attach the hanger. However, the exact positioning of the hanger to the overhead deck was at the discretion of the individual. As a result, trade workers spent much time interpreting blueprints and identifying potential interferences (e.g., pipes, shelves, drawers) before they could fabri-

cate and install a hanger. The process took approximately four hours per hanger to find a location. To resolve this situation, EBQP developed detailed work instructions which simplified the fabrication and installation of electrical hangers.

EBQP uses a CATIA product model to generate the detailed work instructions. These instructions provide a precise drawing that shows the configuration and exact location for each electrical hanger. For areas that require multiple hangers, a paper template is also generated so trade workers can identify precise stud locations for the hangers. The hangers are currently fabricated on the shop floor. However, the use of detailed drawings opens up other manufacturing options such as fabricating the parts in a specialized shop area or purchasing them from a vendor, and then delivering them in kit form to the assembly area.

Skilled trade workers can now fabricate and install an electrical hanger in a fraction of the original time, and the precise drawings even allow a less experienced trade worker to install a hanger within two hours. The use of detailed instructions also reduces the frequency of rework resulting from improper installation. EBQP is currently exploring the possibility of using this technique for installing pipe hangers.

Implementation of Cold Form in Lieu of Hot Form

Hot forming techniques can be an expensive and cumbersome process for manufacturing complex metal parts. Each part being made requires a set of hot forming dies (male/female) to represent its configuration. To form the part, the material undergoes a series of heating and pressing until the final shape is achieved. If the material is manipulated outside its temperature parameters, then its properties will be breached and the material will have to be replaced or annealed/tempered. Typically, ovens are kept in close proximity to where the work is being done. Previously, EBQP enlisted outside vendors to manufacture its complex metal parts using these techniques.

Searching for a more economical and faster way to produce these parts, EBQP developed cold forming techniques using existing equipment. The operation employs a Southwark 3,000-ton press with a 50-inch press opening and a 20-foot width. EBQP also developed multi-functional dies which can readily be made in-house at a fraction of the cost of hot forming dies. The female die is used for a wide range of part sizes, and the male die is used for parts within a specific range of radii. To manufacture a part, the press operator gradually rotates and presses the material

until the desired shape is achieved. The shape is confirmed by using radius gauges.

Although EBQP still has some parts which must be produced through hot forming techniques, the company expanded its capabilities by developing cold forming techniques. This approach enables the company to perform in-house manufacturing, reduce outsourcing, decrease production costs, and improve quality.

Improved Quality and Flatness of Deck Assemblies

Prior to 1997, EBQP used multiple shop groups led by different foremen to assemble a submarine deck structure. Each group defined its own procedures and sequencing for assembly which led to varying results. To minimize distortion, a deck fit-up operation was used and strongbacks were installed to the structure. Next, the groups completely welded the structure and deck plating. Although strongbacks were used, the flatness of a deck assembly could vary three to four times when the typical required tolerance was ± 0.5 inch. The groups then used secondary processes (e.g., flame straightening, hot pressing using portable presses) to correct out-of-tolerance conditions, but the frequency of these processes increased production costs and often induced other bowing and shrinkage. Additionally, deck structures were assembled based on actual design dimensions. As a result of shrinkage caused by extensive welding operations, the final product often did not meet length and width requirements.

EBQP resolved these issues by optimizing and standardizing the assembly sequence for its deck structures. In addition, only one foreman oversees all work. Expected weld shrinkage is now accounted for in the initial deck fit-up operation which enables the final product to meet length and width requirements. After fit-up, the groups weld the first side of the structure and attach one-inch, reverse bow strongbacks to it. Next, the assembly is turned over and welded to laydowns on the assembly fixture. The groups then weld the second side and add the deck plating. The structure is then turned over and the strongbacks are removed.

Since EBQP implemented a standardized sequence, deck assembly flatness has improved and the bow is now uniform. In addition, minor adjustments can effectively be resolved by flame straightening the assembly. EBQP's new approach to submarine deck structures minimizes the use of secondary processes, reduces overall costs, and improves the quality of the deck structure.

Manufacture of Hangers

In 1994, EBQP recognized the need to improve its hanger fabrication process. At the time, pipe fitter (hanger) mechanics would order the necessary materials to fabricate the hangers for a specific job. In most cases, the mechanics also had to cut and machine this material before they could make up the final hanger assembly. This practice resulted in excessive material losses and reissues, and impacted the cost and schedule of the job. Next, EBQP tried to make improvements by outsourcing its fabrication process to a subcontractor. Although hanger quality did improve, this solution was still too costly and time consuming. Finally, the company tasked one of its experienced supervisors to find a solution to these problems. As a result of his efforts, EBQP developed a Hanger Fabrication Shop.

The Hanger Fabrication Shop ensures that all hangers are fabricated in a timely and economical manner. The Shop features six specialized work areas and uses employees who are cross trained in the operations of each area. These six areas are:

- Kit Area — Raw material is received and kitted for each job.
- Prep Area — Raw material is precut and shaped to size.
- Fit Area — Fit-up is done prior to welding.
- Weld Area — Hangers are fabricated by welding.
- Blast and Powder Paint Area — Fabricated hangers are cleaned and painted.
- Final Assembly Area — Completed hangers are assembled and shipped.

In addition, the Hanger Fabrication Shop uses a process control system to ensure that all completed hangers meet the requirements specified by the customer. Since implementing this Shop, EBQP reduced the time to fabricate and assemble a hanger from 14 hours to 4.8 hours. While this is a significant saving over the previous fabrication methods, the Shop's employees continue to seek new and better methods of improving the current process.

Manufacturing Resource Planning Metrics

Defense budget cuts, especially those that affect submarine production rates, have forced industry to become very cost conscious. EBQP responded to this challenge through the innovative use of its existing Manufacturing Resources Planning (MRP) software to control cost.

In 1989, EBQP purchased the MRP II system and modified it to meet the specific needs of the facility. Capabilities of this commercially available software include job planning and the collection of labor hours and historical trends. The system compares data against baseline numbers, such as actual hours from a previous submarine project or estimated hours when a new component is initially built. The MRP II system performs the comparison at various levels (e.g., corporate, job, supervisor, trade) and tracks metric performance in many ways (e.g., by date, by job). In addition, expected performance improvements can automatically be figured into the calculations. In EBQP's case, a 20% improvement factor is included for most of its current work. The hours allotted for a job are 80% of the actual hours used on that job previously. Deviations can be identified such as in top ten lists, and each work order can then be evaluated for process improvements.

The MRP II system provides EBQP with management information and work scheduling system capabilities. By using MRP metrics, the company can identify areas for improvement to reduce production costs, increase product quality, and improve work performance.

Mini Crib System

EBQP incorporated a Mini Crib system into its operations to reduce the amount of time that employees spent on obtaining consumables and tools for their work assignments. The previous practice involved stocking all consumables and tools in a main tool crib. Employees who needed an item would leave their individual work centers and go to the main crib's location. Here, an attendant handled the transaction and made adjustments to the inventory list for the items issued. Employees then returned to their work centers to complete their tasks. As a result of this practice, valuable time was spent away from the job in order to obtain low cost or high volume items. In addition, no control existed at the departmental level for managing costs associated with these transactions. Therefore, accurate job estimates were not possible. EBQP determined that the cost spent on placing the consumables and tools at the individual work centers would more than offset the time spent by employees waiting for items at the main crib.

To implement the new approach, EBQP set up mini cribs at the individual work centers. Inventory information for these cribs are obtained from data provided via history reports generated by the Automated Tooling Inventory Control Tracking System. The mini cribs

are prestocked at the main crib and then moved to the work centers. Attendants assigned to manage the mini cribs are responsible for keeping them stocked. Restocking charges are issued to the work center after replacement items are delivered. Weekly reports are also generated to indicate usage, expenditures, and number of trips to the main crib for non-stocked items. Based on this information, work center supervisors can adjust the stock levels and inventory makeup.

The Mini Crib system provides employees with easy accessibility to the consumables and tools they need to complete their job assignments. Since implementing this system, EBQP reduced the number of trips to the main crib by about 40% which results in direct labor savings to the customer. This approach allows the company to reduce its operating costs, and the employees to increase the quality and performance level of their work.

Modular Construction and End Loading

EBQP has become a leader in applying modular construction to shipbuilding. In the past, most internal components were installed after the hull sections were welded together to form the finished shell. EBQP shipped empty hull sections to the Groton facility for assembly. Here, the sections were joined together and then top-loaded with internal components and structures. This method required workers to cut access holes in the shell and set up interior structure so materials/equipment could be landed and installed within the compartments of the hull. Since cutouts were kept to a minimum, only moderate-sized assemblies fit through these openings. Larger units were loaded as subassemblies and materials, then moved to the proper location for final assembly. In addition, support systems (e.g., electrical, piping, ventilation, hydraulics) were installed sequentially due to trade interference. On-hull construction typically creates poor work accessibility and makes material handling difficult. The sequence for installing the components and assemblies created major scheduling challenges for EBQP. To prevent areas within the hull from becoming inaccessible, the ship was literally built from the bottom to the top. However, work stoppages were frequent as the working conditions within compartments became too crowded and chaotic for multiple trade workers to complete their assignments.

By switching to a modular construction approach, EBQP performs most of its shipbuilding processes in a controlled shop environment with improved accessibility and system testing capabilities. The process begins by dividing the hull into multiple sections. Each section is treated as a separate component and outfitted with its corresponding assemblies and equipment. Internal decks are now fully assembled, welded, outfitted, inspected, and tested in an open environment (Figure 2-2) prior to being installed in the hull section. To position these sub-modules inside the hull section, EBQP uses one of two sliding methods. The sub-module is either suspended from an overhead crane rail and pulled into position, or rolled on a transporter across a rail into position. Initial outfitting of hull cylinders is now accomplished with the hull section in the vertical position, allowing easy crane accessibility for placing components in the hull from above. After the cylinders are rotated to the horizontal position, sub-modules can be end loaded into the hull. Optical tools are used to ensure that the assembled systems will integrate with the next hull section based on the true main axis of the ship and a measuring grid system. This approach allows EBQP to simultaneously assemble and outfit all hull sections in an open environment, and then bring them together for final assembly. The advantages of off-hull outfitting include greater accessibility to work areas, ability to outfit larger assemblies, and a safer work environment.

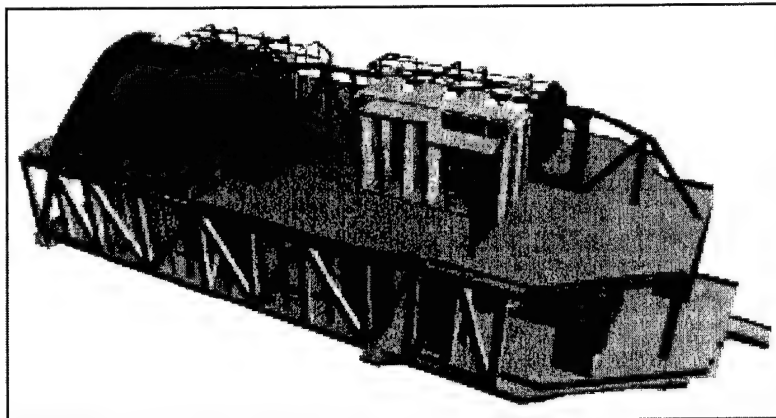


Figure 2-2. Modular Construction

Since module construction largely eliminates trade interference, many construction processes are now done in parallel to decrease production cycle times. In addition, system testing is being performed on each hull module prior to shipment. This approach reduces the testing requirements of an assembled submarine, where corrective action can be expensive. Since imple-

menting modular construction, EBQP significantly improved quality and reduced its labor costs. The company illustrates its off-hull deck outfitting and assembly benefits by the 1-3-8 rule. Using this rule, the labor comparison for a similar task would be: one hour of effort if done in the shop; three hours of effort if done off hull; and eight hours of effort if done inside the hull. Although the 1-3-8 rule does not take rework into consideration, it does show the importance of performing a task as early as possible to gain the most benefits. EBQP is using modular construction with positive results, and will continue to expand on its use for future projects. By using integrated design and manufacturing systems, the company enhances the capabilities of modular construction and decreases the turnaround times for constructing ships.

Multi-Trade Program

In the past, EBQP used a cyclical process (Figure 2-3) for constructing submarines, which meant most of the skilled trade tasks (e.g., structural, installation) were done in a specific order. When production rates were high, submarines were built simultaneously. Skilled trade workers who finished their tasks on one submarine would then start work on the next. With defense budget cuts decreasing submarine production rates, this approach is no longer an option. In 1990, EBQP initiated the Multi-Trade program to improve its modular construction process and foster a flexible workforce.

Through this program, trade workers are offered extensive training in alternative trades including

shipfitting, welding, piping, mechanical, ventilation, electrical, and sound damping. The goal of the program is to train workers in three trades outside their specialty. To become qualified in a trade, workers undergo 96 hours of classroom training, half on company time and half on their own time. Once they successfully complete these classes, workers are then assigned to the modular construction area to perform 40 hours of on-the-job training under supervision. Currently, 135 workers are enrolled in the program.

EBQP organized the Multi-Trade program under a single management unit (modular construction). This approach allows skills to be used where they are needed most and reduces direct competition among trades for available skilled workers. When possible, workers are cross trained in complementary trades to capitalize on efficiency. Typical examples include pipe welders training to become pipe fitters so one person can fit and weld piping, or shipfitters training to become pipe fitters since the basic terminology and techniques are identical in both trades. EBQP plans to implement the next phase of the program in 2000. This phase will focus on skill/career development by combining trade training with academic learning through a formal apprenticeship. EBQP also hopes to use the Multi-Trade program to develop next generation workers to replace its aging management team and workforce.

Since implementing the Multi-Trade program, EBQP improved the efficiency of its modular construction process, increased the flexibility of its workforce, and gained significant cost savings. Approximately 10% of the workforce participates in the

program, and an average of 30% of the workers' time is spent outside their core trade. By adding variety to the job, EBQP significantly improved the workers' morale. The Multi-Trade program also operates as a key element in dealing with manpower requirement fluctuations. As a result, EBQP does not need to increase/decrease its workforce to match current workloads. During modular construction of the Seawolf-class attack

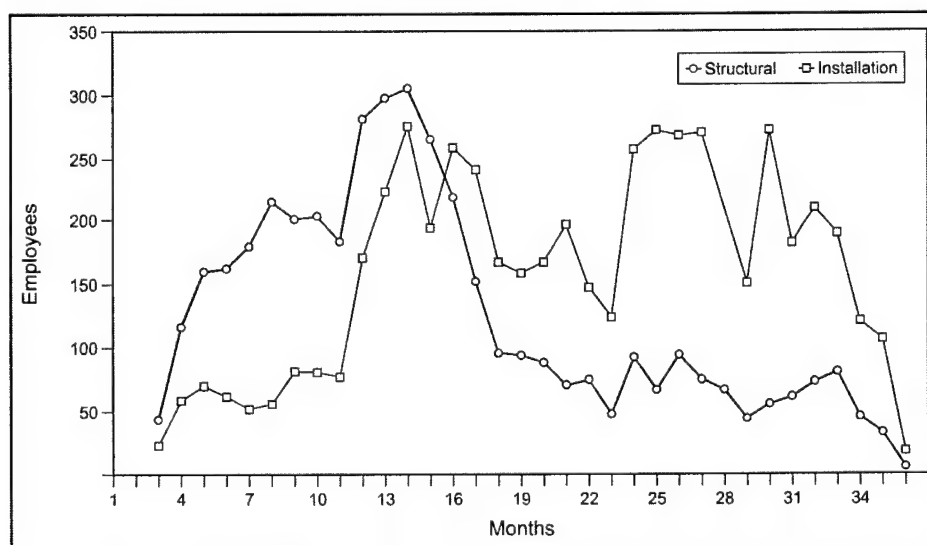


Figure 2-3. Cyclical Trend of Trades Involved in Submarine Construction

submarine, EBQP reduced its labor hours by 25% compared to the time spent on the previous ship in this class. This feat increased the average improvement of the facility as a whole by 17%.

Nesting Process for Steel Plate and Sheet Metal

Prior to 1989, EBQP used paper or waxed cardboard cutouts to manually determine the layout and orientation of items on steel plate/sheet metal for the Production Department. Workers determined best fits through trial and error; manually key punched cards; used proof plots and nest tape validations to ensure proper location of items; and hand-delivered and loaded paper tapes on shop numerical cutting machines. The company also used a manual remnant control system (card file) to track jobs, and needed extensive storage space to house particulars (e.g., 1:10 plots, paper tapes, nest tape plots, punch cards). Change control was difficult and lacked flexibility for reusing a nest without performing significant rework. Since training costs were high, skilled workers were almost non-existent. The company's scrap rates were 34% for unused parent material and 12% for as-cut parts, mostly due to plan and layout errors. In 1989, EBQP improved its practices by implementing a computerized Nesting process.

The Nesting process utilizes OPTINEST Company's OPTINEST and OPTIPUNCH software for steel plate and sheet metal, respectively. The process is also fully integrated into EBQP's MRP II system, a management information and work scheduling software package. A work order for cut parts initiates the Nesting process. Component item geometry as well as order and label information are downloaded from the MRP II database in the IBM mainframe library. Stock for cutting is then specified based on previous remnant files, fractional (partial) plate/sheet listings, or new plate/sheet. The OPTINEST software automatically optimizes the component positions and uploads data (e.g., for cuts, markings, plots) to the mainframe. Nest data in the MRP II system is then electronically provided to the Production Department, where orders are released and equivalent part numbers are automatically identified electronically. The software automatically generates the traveler paper work (including nest and part sketches) and move tickets, along with automatic shop floor updates. Once the parts are cut, shop floor workers wand a barcode to close out an order and identify parts in transit. Verification of the closed order is done electronically.

EBQP's Nesting process differs from other software programs because it requires minimal staff to operate and possesses a high level of automated electronic integration into the MRP II system. Since implementing this process, the company:

- Decreased part nesting time from 21 days to an average of two to five days;
- Reduced nesting staff from 12 nesters and two validators to three-quarters of a person;
- Decreased subsequent part processing time from 63 days to 3.5 days;
- Reduced processing staff from seven planners, three operators, and two material controllers to three planners and three operators/material controllers;
- Determined that 80% of all parts are now nested in operations which last less than 30 seconds per plate/sheet;
- Decreased scrap rates for unused parent material from 34% to about 11%; and
- Decreased scrap rates for as-cut parts due to errors from 12% to essentially 0%.

Nuclear Pipe Shop

EBQP set up its Nuclear Pipe Shop as a controlled area with restricted access, a strong organizational structure, and the ability to maintain system cleanliness. These attributes, in conjunction with the knowledge and experience of the employees, foster the Shop's high level of quality and precision in manufacturing nuclear products. Here, reactor plant piping assemblies, stations, components, and associated pipe systems are produced and inspected at the highest level possible prior to installation on submarines. The Shop also uses multi-skilled tradespeople. Pipefitters are qualified to MIL-STD-767 Grade A cleanliness requirements, and perform visual and dimensional inspections of nuclear pipe joint fit-ups. Pipewelders are certified to NAVSEA 250-1500-1 and MIL-STD-278 welding specifications, and assist in the pipefitting operation and inspection processes. NAVSEA's approval to allow tradespeople to become qualified on certain inspection processes has increased employee awareness of acceptance criteria and, in some cases, eliminated redundant processes thereby decreasing staff requirements.

EBQP also uses a Radiographic Testing (RT) Pipewelding Team (e.g., pipewelders, engineers, managers) to control which pipewelders are assigned to pipe joint welds requiring radiography inspection.

The Team is divided into active and inactive members. Inactive members are those not currently performing pipe joint welds subject to radiography inspection, but who are qualified to do so. To move to the active status, members must demonstrate their ability to perform RT quality welds by satisfactorily completing a series of tests. This arrangement allows the active group to expand and contract based on EBQP's production needs. In addition, the company has seen a downward trend in its pipe RT rejection rate, from 3.1% in 1990 to 0.6% in 1999 (year to date).

Because of the high level of production and the excellent quality obtained, automated equipment is always the first option considered when welding pipes. Therefore, the Pipe Shop operates various types of automated pipewelding equipment including five horizontal rolled automatic gas tungsten arc stations (three of which are jet-line computer operated); two diametric orbital auto gas tungsten arc machines; and one horizontal rolled sub-arc station. Pipefitters are instructed to sequence fit-ups of pipe details to allow for automatic welding. In addition, they use a variety of jigs and fixtures to properly position pipe joints for maximum use of automated welding equipment. Approximately 43% of pipe joint welds subject to RT NDT are welded with an automated process. The Shop's horizontal rolled automatic gas tungsten arc stations are equipped with a hot wire gas tungsten arc welding accessory, which is widely used during the clad welding process for surface hardening and corrosion resistance applications. Welding equipment operators are also qualified to operate various automated pipe welding equipment using multiple processes. This approach provides the company with flexibility for its changing production requirements.

Pipe Marking, Cutting, and Bending

EBQP automated its pipe marking, cutting, and bending processes by implementing Direct Numerical Control (DNC) and Computer Numerical Control (CNC) systems. In the past, most operations were done manually.

For its marking and bending processes, the company uses an automated pipe marker and cutter machine built by Danti Precision in Woburn, Massachusetts. This prototype machine is the only one of its kind in the world, and consists of four stations: loading, marking, cutting, and unloading. The operator downloads information from an engineering database to the machine through a DNC system. Raw lengths of pipe, up to 21 feet long with a National Pipe

Standard (NPS) diameter of 0.25 to 6.0 inches, are placed in the loading station. The machine feeds the pipe to the marking station, where identification marks are etched on the material by a Telesis pin stamp marker. Next, circular lines are drawn on the pipe by a Video-Jet ink-jet system to designate the final cut points and initial tangents of each bend. The machine then moves the pipe to the cutting station where it is incremented through a CNC band saw and cut to length. The pipe sections are sent to the unloading station, where the machine grips each section and feeds the completed product to the operator. When done manually, these operations required eight to ten workers. The automated system now requires only two operators and produces more accurate products.

For its bending process, the company uses four CNC pipe bending machines. These machines can handle pipes with an NPS diameter of 0.25 to 10.0 inches, and produce final products of 2D, 3D, and 5D. The CNC benders are equipped with boost capability which improves bend quality by reducing pipe wall thinning on tight radius bends. The operator downloads the bending program from the design database to the machine through a DNC system. The DNC system automatically adjusts the CNC programs with pipe spring-back and radial growth compensations.

Since implementing these automated systems, EBQP has effectively improved its pipe marking, cutting, and bending processes. These systems enable the company to increase product quality, decrease staff requirements, and reduce turnaround time.

Super Piece Mark Process

In the past, EBQP created some parts by fabricating many small plates and assembling them in a piecemeal fashion. Individual small plates were cut to size and formed with edge preparations prior to assembly. Irregular fit-ups typically occurred due to tolerance build-ups, which increased the time to fit-up the pieces and reduced the end-item dimensional accuracy. Shrinkage from each weld also caused the welding process to contribute to inaccuracies. EBQP resolved these problems by initiating a Super Piece Mark process whereby several metal plates are combined to make one large piece mark.

The Super Piece Mark process enables EBQP to create a part from raw flat plate that is welded together. Edge preparations now exist only on the edges that make up the welded seams of the assembly. The pieces are then fit-up, and reference lines used for

line-up are applied at final trimming. Next, the pieces are welded based on a supplementary work package and sketch. A computer-controlled burning gantry uses electronic data taken from the wire model to trim the assembly to size.

The Super Piece Mark process enabled EBQP to minimize irregular fit-ups and weld shrinkage; improve the dimensional accuracy of parts; and reduce stack-up tolerances due to as-built conditions. Since the majority of the welding process is now performed in the flat configuration, the quality of the weld joints has also improved. EBQP can produce a final assembly configuration within 1/8 inch of the drawing requirements.

Trade Interface Program

On any particular day at EBQP, up to 100 tradespeople are involved in the construction, assembly, and installation of a hull section. As a result, trade interfacing becomes an important factor in ensuring the prioritization of prerequisite sequence issues (e.g., schedule, cost, productivity, safety). In the past, many obstacles hindered trade interfacing such as separate agendas by the trades, congestion of work environment, and lack of coordination and communication among trades. The result was an inefficient process and an ineffective use of personnel. To resolve this situation, EBQP developed the Trade Interface Program.

The Trade Interface Program uses various types of meetings to promote communication and coordination among the main and support trades (e.g., shipfitting, welding, mechanical, electrical, sound damping, riggers, staging carpenters). These meetings are conducted on a daily or weekly basis; involve either all trades or just pertinent ones; address a variety of topics; and generally are completed within an hour. EBQP uses Plan of the Day to address all trades' concerns in a timely manner; Module Review to coordinate the sequential construction of hull sections; Key Events to ensure that trade interference does not impact construction milestones; and Support Trade Plan to effectively schedule the workloads of support trades. Additional meetings include Shift Turnover, On-Hull Sequence Briefings, and Administrator Passdown. Each meeting proves to be an effective and necessary tool for interfacing the trades during modular construction.

The Trade Interface Program has proven to be a highly effective way for EBQP to increase communication and coordination among the trades. Since implementing the program, the company improved the work environment; increased product quality;

and reduced turnaround time. In addition, the program is quickly gaining acceptance by the shipyard trades.

Welding Quality Accountability

In the late 1970s, EB Groton developed the Shipyard Weld Status System (SWSS) to provide quality accountability for the structural welds of submarines. Every weld on a ship is assigned to a unique SWSS record, which provides details on the weld joint such as material type and thickness; compatible weld processes and filler wires; and sign-off points for the welders and inspectors. Tracking weld quality is a formidable task since each submarine typically has about 300,000 structural welds. The initial version of SWSS required weld supervisors to create handwritten chits for distribution with the weld wire. Supervisors had to research data so they could match a qualified welder with the activity, determine the proper weld procedure, and select the correct weld wire. However, this fact-finding task was complex, time consuming, and easily introduced errors into the process.

To resolve this situation, EBQP developed the Automated Weld Process Selection System (AWPSS) in the late 1980s. AWPSS is tied into SWSS as well as EBQP's Personnel Qualification System. Now, supervisors can easily locate information pertaining to welder qualifications and welding specifications. In 1998, EBQP enhanced SWSS by implementing the Electronic Record System which was especially designed for the Virginia-class submarines. This system eliminates the previous paper tracking method; allows employees to electronically sign-off on a routing activity; prevents activities from being done out of sequence; and checks the qualification of the employee signing-off on an activity. In addition, the system logically checks the NDT time delays which prevent an inspector from signing-off on work before the proper due date.

Since implementing these systems, EBQP simplified its weld tracking and quality control processes. The result is greater visibility regarding the overall structural status of a ship under construction and the ability to determine the current status of any structural assembly. Management can now quickly determine how fast an activity is progressing. By using AWPSS, EBQP improved its welding quality and decreased the preparation time for chits from two hours to just a few minutes. By using SWSS, the company ensures that the activity steps are signed-off in the proper sequence and can track the number of completed welds.

Facilities

Energy Management System

EBQP implemented an Energy Management System (EMS) to regulate various processes and operations throughout the company. Typical activities involve air compressors; steam valves; heating, ventilation, and air conditioning (HVAC); argon; and electricity. Using Carrier Comfort Works' software and sensors, EMS performs two major functions: (1) constantly monitors critical facility operations via sensors and (2) controlling standard on/off processes so output is proportional to demand. This computer-based system also monitors alarm points, and sends visual warnings to designated computer terminals and pagers when triggered. Monitored alarm points include air compressor intercooler temperatures, oil temperatures, air pressure, HVAC air handling fans, office space temperatures, relative humidity, carbon monoxide content, and temperature parameters in critical areas.

The following are a few examples of processes and operations regulated by EMS:

- Office space temperature — EMS controls the office space temperature to within one degree variance by using an algorithm to read the outside air temperature, current space temperature, and desired temperature. Based on these inputs, the system adjusts the heating valves, cooling valves, and outside air dampers to maintain the set point temperature.
- Facility air pressure — EMS constantly monitors the compressed air system to maintain the desired facility air pressure. As pressure rises due to higher demands, an anticipator routine ramps up the lead compressor to a higher output. If this is insufficient to meet demand, then EMS brings the secondary compressors on-line. Once the desired pressure is achieved, the system will begin to back down the compressors to avoid over-pressurization.
- Outside air pressure and steam heat valves/chiller plant — EMS regulates the steam heat valves and the chiller plant to maintain a comfortable working environment

in the buildings. Based on the outside air temperature, EMS automatically adjusts the steam heat valves and the chiller plant for heating and cooling the offices. The system also controls the re-circulation route for the air compressor cooling water.

- Tabulating usage and generating reports — EMS automatically tabulates utility usage (e.g., argon, electricity, air compressor) by the company. The system identifies each item's unit cost, and then determines the facility's operational cost based on an unoccupied day, typically Sunday. EMS uses this information to generate weekly reports which are distributed to facility management. These reports help EBQP monitor and troubleshoot its processes and operations.
- Future function — EBQP plans on using EMS to control the company's overhead lights. A production facility is being constructed with 165 lights, each at 1,000 watts. EMS will monitor the ambient sunlight, and scale back the artificial light intensity during daylight hours to reduce the facility's electricity usage.

Since implementing EMS, EBQP significantly reduced its energy costs. Figure 2-4 shows a substantial decrease in overall steam costs since 1996, and a 51% reduction in 1999 year-to-date costs compared to last year. Electricity costs for the first two months of 1999 were also reduced by 15% and 11%, respectively, compared to 1998 figures. EBQP hopes to reduce its 1998 overall energy costs by 10% for 1999. Additional benefits from using EMS include task reassignment of personnel who previously monitored critical facility

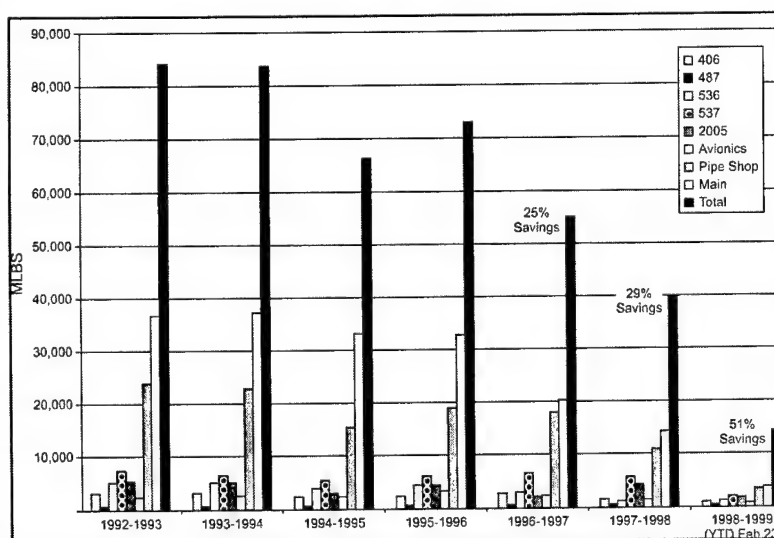


Figure 2-4. Yearly Heating Season Steam Usage

operations, and simplification of maintenance planning since EMS automatically provides notification when preventive maintenance is required on monitored machines.

Management

Automated On-Line Personal Protective Equipment and Restriction Certification

In the past, EBQP used restriction reports to notify supervisors of their employees' physical work restrictions. The Human Resources department entered the information into a logbook and forwarded a copy to the employee's supervisor. After reviewing the copy, the supervisor placed the report into the employee's file. More often than not, this information faded from memory. As a result, employees often were assigned tasks beyond their physical restrictions and incurred subsequent injuries. In addition, medical personnel had to manually search medical files to locate an employee's work restrictions. In 1998, EBQP addressed these issues by upgrading its Automated Time and Attendance (AT&A) system to provide easy notification and accessibility regarding physical work restrictions. At that time, the company also adjusted the system to handle personal protective equipment (PPE) requirements and training per Occupational Safety and Health Administration (OSHA) regulations.

The upgraded AT&A system is user friendly and easy to maintain. Only the Human Resources department is authorized to enter the employees' physical work restrictions and PPE requirements/training into the system. This task is completed on a daily basis, and the information is updated as needed. Supervisors can quickly access the information to verify daily labor hours; determine equipment and training needs; and assign tasks within each employee's capability. Since no specific medical information is provided, the work restriction feature does not violate employees' rights.

The new features of the AT&A system provide EBQP with many benefits. Supervisors now access up-to-date information regarding their employees' physical work restrictions and PPE requirements/training, and initiate appropriate actions (e.g., determine task assignments, issue proper equipment, provide additional training). Medical personnel can easily obtain this information without manually searching an employee's medical file. In addition, the

AT&A system is designed to generate reports that track the number of employees in each work restriction category. Since implementing the upgrade, EBQP notes an absence of occupational injuries for situations where employees were performing tasks beyond their physical restrictions.

Community Outreach: School to Career Program

During the early 1990s, EBQP experienced a severe cutback in workload which resulted in an abrupt falloff in employment. By 1996, the company had reduced its workforce from 5,700 employees to about 900. This downsizing occurred during a period of very high unemployment in Rhode Island which compounded the effect on displaced workers and the community at large. Additionally, EBQP had virtually no presence in the local community and rarely recruited. The company desired to reverse this trend, so it initiated the Community Outreach: School to Career program in 1996.

Since many of the displaced workers had left the region, EBQP recognized that its future workforce would largely be composed of inexperienced, recent graduates. Therefore, the company geared its outreach/recruitment efforts toward recent graduates and high school students. The Community Outreach: School to Career program was set up as a way to interest young people in careers at EBQP and foster the company's involvement in the community. Through this program, EBQP participates in high school career and science fairs; maintains active contact of recent graduates via school superintendents; participates in Chamber of Commerce events; and offers facility tours for local students. The company also set up a high school internship where students can earn credits for on-site work during school hours. Through these activities, EBQP is establishing ties with the surrounding community and promoting its facility as an excellent place to work.

Since initiating the Community Outreach: School to Career program, EBQP has become an active participant and recruiter in the local community. As of early 1999, the company's workforce had grown to more than 1,500 employees. Although its goals and approaches are still in the early stages, the program provides a win-win situation for all; promotes a positive image of EBQP; and shows how a company can establish ties to its community even after a period of strain and hardship.

Cost of Quality Program

Quality cannot be compromised when building the most capable and safest nuclear submarines that industry can produce. Accordingly, cost of rework/repair of defects (cost of quality) has always been a topic of discussion in this industry. In the past, shipyards commonly measured only one attribute at a time, and based each attribute on the total number of rejections versus the total number of submittals. In the long run, the shipyards were determining the rejection rate, but not at an hourly level for reworking/repairing defects. In 1998, EBQP initiated the Cost of Quality program which measures overall performance as it relates to quality.

The Cost of Quality program is based on a matrix of 22 elements (e.g., structural radiography welding rejections, braze rejections, test inspection reports, customer concerns, out of tolerance reports, magnetic particle rejections), which represent the major quality indicators for the facility. Data for these elements are gathered from reports generated by the welding engineering department, mainframe queries, quality assurance databases, and manually produced records. The company assigns standard labor-hours for reworking/repairing a defect to each element. The cost of quality metrics are then determined by summing the number of defects for each element, multiplying by the standard labor-hours, and dividing by the total manufacturing labor-hours expended per month by the facility. The company reviews the metrics at monthly Corrective Action Board meetings, and examines solutions to reduce and/or eliminate rejections. The data is also trended to illustrate positive and negative movement of the metrics based on the Board's actions. By using accurate trend analyses, the Cost of Quality program calculates the performance of corrective actions used to reduce/eliminate specific defects.

Since implementing this performance management system, EBQP can easily evaluate its overall quality performance and make appropriate adjustments. In 1998, the company achieved a 1.3% performance rating, which is considered extremely good in the shipbuilding industry.

Diversity Group

Over the past 20 years, many transformations have occurred at Quonset Point including changing from a naval air station to an industry site; evolving from a

structural fabrication shop to a modular construction facility; and downsizing to a fraction of its workforce and then rebuilding. Likewise, the workplace is now a diversified environment consisting of employees with different cultures, races, religions, social classes, sexual orientations, ages, and physical/mental capabilities. After EBQP's workforce began to level out in 1997, a small group of minorities approached the Human Resources Department with issues concerning their present and future roles in the company. In response, EBQP set up the Diversity Group as a way to foster cultural and employee relations.

The Diversity Group teaches employees how to interact with one another, acknowledge cultural differences, and treat everyone with respect. By educating the workforce on diversity issues and topics, the Group strives to achieve an environment that attracts, develops, and retains the most qualified employees at every level of the corporation. Companies that value their employees typically create a workforce with higher morale, lower turnover, and more efficient and productive skills. Although still relatively new, the Diversity Group has initiated some ways of addressing its goals and objectives:

- Serves as company ambassadors in the diversity effort
- Meets every two weeks to discuss issues and projects
- Assists with job recruiting efforts
- Attends job fairs to inform individuals of available positions at the facility
- Identifies minority agencies and newspapers
- Developed a newsletter to inform the workforce and local community
- Established a partnership with the Trudeau Memorial Center for providing services to adults and children with disabilities
- Grown to 18 employees, further diversifying itself by gender, race, and occupation

During the next ten years and beyond, EBQP expects its workforce to continue growing, and anticipates the development of new opportunities and challenges. Inevitably, the Diversity Group plans to be instrumental in providing support and enhancing the company's cultural and employee relations. Future plans by the Group include hiring an outside consultant to help develop a mission/vision statement, initiate a workforce training program, and set up a mentoring program.

Employee Assistance Program

EBQP provides a comprehensive employee assistance program, known as Optum Care 24, for its employees and their dependents. This program is administered by the United Healthcare Corporation as part of EBQP's employee healthcare plan. Assistance is available 24 hours a day, seven days a week.

Optum Care 24 addresses all aspects of health and well being, and provides accessibility to information and resources for almost any problem. Employees access the services by calling a toll free number. Trained counselors and nurses are available to help with a wide range of issues such as relationships and family troubles, physical health concerns, substance abuse, chronic health ailments, minor medical emergencies, financial worries, work-related stress, questions about medication, and personal legal problems. These counseling services are private and held in strict confidence between the counselor and the client. The program is voluntary except in cases of substance abuse or psychological problems affecting an employee's work performance. In these situations, the company may require the employee to participate in the program. The first seven counseling sessions are free. Any additional sessions are covered under the employee's healthcare plan. As part of the counseling services, clients receive additional information and in-depth education as needed.

Optum Care 24 offers a wide range of information and helps clients develop a plan of action. For assistance beyond what the program can provide, clients are referred to an appropriate resource. Regular follow-ups are also conducted to ensure that clients are getting the help they need. Another feature of Optum Care 24 is the audiotape Health Information Library. Employees call the same toll free number, and select topics from more than 350 recorded health messages. This same information can also be faxed.

Employees consider Optum Care 24 to be a valuable service at EBQP. All feedback on the program has been very positive. This employee assistance program offers much better service than can generally be obtained through the Human Resources Department alone.

Employee Community Services Association

EBQP established the Employee Community Services Association (ECSA) as an outreach program to help employees and the community. Set up as a non-profit organization, ECSA is certified by the Rhode Island Secretary of State, and managed by an ECSA

Committee composed of hourly/salary employees representing many disciplines of the workforce. The Committee oversees the collection and distribution of donated funds from the workforce to organizations such as the United Way, Requested Assistance, and Catastrophic Needs.

The ECSA Committee meets monthly to review monetary requests from organizations. To qualify for donations, the requesting organization must be non-profit and benefit the welfare of Rhode Islanders, nearby communities, or any EBQP employee and/or family. If the criteria are met, the Committee votes on whether to donate and how much to give. To show EBQP contributors how their donations are used, the Committee publishes an annual list of recipients and periodically posts thank you notes from these groups on cafeteria bulletin boards. The Committee can also hold emergency meetings whenever an EBQP employee suffers a catastrophic event which causes immediate financial hardship. Again, certain criteria must be met prior to monetary assistance, and the Committee then votes on eligibility and the amount to be awarded. In these cases, donations to individual employees are kept confidential.

During October and November, ECSA conducts an annual campaign that coincides with the Rhode Island United Way Campaign. Employees are encouraged to donate through payroll deduction. By donating more than \$1.50 per week, employees become eligible to win one of 50 prizes given away by EBQP. During the campaign, the Committee promotes awareness through banners, flyers, and verbal communication to keep employees informed on the drive's status and goals. Although the United Way is the largest recipient of contributions, employees have the option to direct their donation to another charity. Other activities that ECSA is involved with include the Easter Seals Telethon; Muscular Dystrophy Telethon; Rhode Island Special Olympics; Rhode Island Community Food Bank; and Santa's Helper.

ECSA is an effective outreach program that is strongly supported by management. Since EBQP implemented this program, the average contribution per employee has steadily increased since 1993. Typically, 65% of donations go to the United Way, 20% to Requested Assistance, and 15% to Catastrophic Needs.

Entry Level Mentor Program

Major downsizing during the 1990s reduced EBQP's workforce by 80%. As a result, the company's skill mix became disproportionate with all remaining employees being highly skilled and near retirement

age. Having gone so long without hiring, EBQP decided to reinvent the process by setting up the Entry Level Mentor program. The goals of this program are to improve the skill mix; establish a diverse, flexible workforce; provide a teamwork environment; educate/train for promotional opportunities; emphasize safety; reduce production costs; and develop employees with overall job satisfaction.

The Entry Level Mentor program starts with an extensive applicant screening process which includes several interviews; a facility tour; evaluation of mathematic skills; review of transcripts, diploma, and references; and a medical/drug screening. Based on this input, new hires become Fabrication Technicians and are assigned a work shift, an initial trade, and a first mentor. Over a three-year period, Fabrication Technicians will receive on-the-job training in three different trades, each for a one-year duration under a different supervisory mentor. On the first day of work, trainees begin attending a two-day orientation session that introduces them to the facility, its operations, and its policies. The initial 17 weeks constitute a probationary period followed by a minimum of 80 hours of classroom training each year. Trainees must record their daily assignments in a logbook which is signed weekly by their mentor. Mentors meet bi-weekly with their department heads to review the program and trainee status, and monthly with a Human Resources representative to provide progress status, solicit recommendations, and answer any questions. In addition, the Site Manager meets bi-monthly with each Fabrication Technician class to receive feedback and discuss the company's goals and philosophy.

By implementing the Entry Level Mentor program, EBQP strives to welcome new employees; reduce work assignment anxiety; minimize the learning curve by continued attention to performance; and develop interpersonal skills, leadership, and coaching skills among experienced employees and supervisors. This well-designed program will provide EBQP with a flexible, lean production workforce for the future. Although presently in its infancy, the Entry Level Mentor program could serve as a model for other industry sectors which face similar workforce issues and challenges.

Facility-Wide Communication Program

EBQP recognizes communications as an important tool for clearly disseminating announcements, updates, policies, and procedures throughout the facility.

Even during its massive downsizing, the company still maintained lines of communication for security and safety issues because of their criticality to the workplace. However, the exchange of general information diminished due to resource constraints. Now as the company rebuilds, the communication mechanisms are also being re-established.

The Facility-Wide Communication program is a gradual process, but utilizes some low technology and innovative methods:

Security Issues

- Security Bulletin — Used as the primary communication medium, published periodically, and provides employees with need-to-know or adverse information.
- Special Notices — Used as needed to address special topics like alcoholic beverages during the holidays.

Safety Issues

- Safety Training Presentations — Presented on a monthly basis by supervisors to communicate safety issues/training to hourly employees. All employees must sign a roster sheet to document their attendance.
- Safety Quiz — Distributed during Safety Training Presentations. Employees who complete and return the quiz receive a coupon redeemable for a free dessert in the cafeteria.

General Issues

- Weekly Information Bulletin — Addresses general topics (e.g., safety, quality, recreation) which supervisors review with their employees. All employees sign a roster sheet to indicate acknowledgment of content.
- Diversity Newsletter — Discusses multi-cultural events, programs, information, and human interest stories (e.g., retirements, family highlights).
- Electric Boat News — Provides items of interest for the Quonset Point and Groton facilities via a company newspaper.
- All Team Notices — Used as needed to announce items of general interest (e.g., general raises, special equipment sales, government facility inspections).
- Quarterly Information Briefings — Presented on a quarterly basis by the Site Manager to all employees. This state-of-the-state presentation discusses cost and performance goals as well as achievements.

- Notes from the Site Manager — Presented on a monthly or bi-monthly basis by the Site Manager to all employees. These notes provide information and feedback from top level management in regard to business structure and activities across the various shops.
- Bulletin Boards — Used to display job postings and special notices at the main gates.
- EBQP Bulletins — Used to display corporate-wide announcements of major events such as large contract awards.
- Automated Time and Attendance System — Used to announce facility events (e.g., blood drives) via security badge reader screens.

The Facility-Wide Communication program enables EBQP to keep its workforce informed on the latest information regarding security, safety, and general issues. By utilizing low technology and innovative methods, the company finds new ways of effectively communicating important points to its targeted audience — an industrial workforce engaged in heavy fabrication with critical safety and security requirements.

Flat Organizational Structure

Prior to 1992, the organizational structure of EBQP's fabrication and assembly operations consisted of seven layers of management. This arrangement created a supervisory ratio of 12:1; contributed to high overhead and indirect labor costs; and hindered the free flow of information throughout the facility. Administrative actions were quite slow due to the lengthy chain of command. As changes in the defense market brought about downsizing and pressure for leaner processes, EBQP gradually re-engineered its operations into a very flat organizational structure.

Today, EBQP uses only three layers of management (Site Manager, Superintendent, and First Line Supervisor) for its fabrication and assembly operations. This arrangement increased the supervisory ratio to nearly 15:1, and reduced overhead and indirect labor costs by more than 50%. EBQP accomplished these changes through attrition, lateral moves, and reclassification of positions. With a leaner structure in place, the company eliminated many administrative redundancies and accelerated review times for budgets, performance, and overtime actions. In addition, many process steps were reduced or eliminated.

Since implementing the flat organizational structure, EBQP has realized many benefits. Communications significantly improved though increased interaction among tradespeople, staff, and top level man-

agement as well as between internal organizations. Productivity showed a marked improvement, and overhead decreased because more resources were being applied to direct work charges. As part of the streamlining effort, EBQP began outsourcing overhead activities such as facility maintenance and janitorial services. The most instrumental benefit was the overall enhancement of the process improvement culture within the organization, which continues to contribute to improvements in productivity. This leaner management structure helped provide a 16% savings on the third Seawolf-class submarine compared to the second one built at EBQP.

Industrial Safety Program

EBQP set up its Industrial Safety program as a managed system of safety policies, procedures, and training. The program was developed to minimize hazards in the workplace; lower the employee injury rate; reduce Workers' Compensation claims; and help employees quickly identify and correct conditions that may occur in a dynamic work environment.

In conjunction with its policies and procedures, EBQP conducts safety training sessions to help employees improve their work practices and enhance performance. Other resources available to employees include Safety Advisors and Coordinators for guidance; Shipyard Standard Procedures for completing technical tasks in a safe manner; and Standard Procedures for handling a hazardous/safety situation, performing an audit, and keeping informed on the latest OSHA regulations. All departments maintain Division Safety manuals and update them on an annual basis. The company also uses OSHA training sessions to educate supervisors, department heads, and selected hourly employees. During these 20-hour classes, participants enhance their knowledge on OSHA regulations and learn to identify possible safety violations within their work centers.

Another tool is the safety matrix, a checklist used throughout the company which identifies the most frequent types of safety violations in a particular location. Each week, supervisors choose a team leader for their department or work area. Using the matrix as a guide, team leaders conduct a safety inspection of their area. As a result, concurrent safety inspections are performed throughout EBQP, and employees actively participate in the safety, health, and welfare of their co-workers. Other avenues for promoting safety include weekly bulletins; safety recognition; accident investigation techniques; and case management of injured workers.

The Industrial Safety program enables EBQP to educate and empower its employees on safety issues and procedures. Since implementing the program, the company reduced its injury rate by 86%.

Leadership Development and Supervisory Skills Training

EBQP has a long-standing commitment to personal development for its workforce, supervisors, and management. Typically, assistance has been administered through seminars, specialized sessions, in-house training, and tuition reimbursement programs. After the massive downsizing of the early 1990s, the company began rebuilding its workforce and soon recognized the need to revise its management development practices.

Today, EBQP requires all levels of management to complete leadership development and supervisory skills training. The training consists of two programs:

- **Leadership Development Training** — This program is a 24-hour, off-site course developed by the Rensselaer Learning Institute. The course provides a foundation for one-on-one interpersonal skills, and focuses on techniques that support team initiatives, quality improvements, and process improvement efforts. Participants also learn how to address leadership challenges typically found in today's cross-functional workplace, where employee involvement and interaction are increasing.
- **Supervisory Skills and Topics Training** — This program is an eight-hour, on-site course developed by EBQP's Human Resources Department. The course is delivered in four two-hour segments, and deals with personnel issues, employee evaluations, disciplining procedures, the wage system, training requirements, safety and health topics, legal issues, and procedures for new hires. Participants also learn how to sharpen their human resources skills.

EBQP's leadership development and supervisory skills training is a continuous process. Through these programs, the company expands the skills, knowledge, and capabilities of its managerial employees. Those who have completed the training learn how to focus on the situation not the individual; maintain self-confidence and the esteem of others; establish constructive relationships; initiate position actions; and lead by example.

Process Improvement Program

Process improvements are often small changes that put employees' ideas into action and result in enrichment for the company. In the past, EBQP attempted to improve its business base through a variety of techniques including Quality Circles, Suggestion and Recognition programs, and Best Practices teams. Despite their general success, these techniques were often segmented and compartmentalized approaches. Seeking a more effective way to capitalize on process improvements, EBQP developed the Process Improvement Program (PIP) in November 1997.

PIP (Figure 2-5) is a comprehensive and integrated program which focuses on the capabilities, experience, and ideas of the workforce for implementing process improvements. The key to this program is Process Improvement Teams which are formed within and across eight functional areas. This approach promotes participation by employees, enhances communication, and limits discord by understanding the value of individual contributions. The teams average five to six hourly/salary employees depending on the functional area, and are responsible for identifying problems, proposing solutions, and determining drivers for improvement. PIP provides additional services via a staff administrator and up to 11 facilitators who lend assistance to the teams; benchmark PIP methods and techniques; and provide specialized assistance/training as needed for problem-solving and goal-setting processes.

Another feature of PIP is the Process Improvement Template. This simple, easy-to-use tool formats the process improvements into standardized categories: area(s), section(s), concern, action, status, acceptance date, and implementation date. Team members input/update information on templates by using PIP's Process Improvement Tracking system. This Microsoft Access-based system is easy to use and provides real-time access so management can view, track, and analyze process improvements. The system also features search capabilities and a report generator, allowing the creation of reports based on set parameters (e.g., functional area, type of change, department shift, incentive for improvement). Via a Microsoft PowerPoint link, templates and reports can be viewed or downloaded for team meetings and management briefings.

An important element to PIP's success is employee participation, which the company defines as being a member of one or more teams within a one-year period. During 1998, employee participation in PIP was at almost 45%, surpassing the initial goal of 32%.

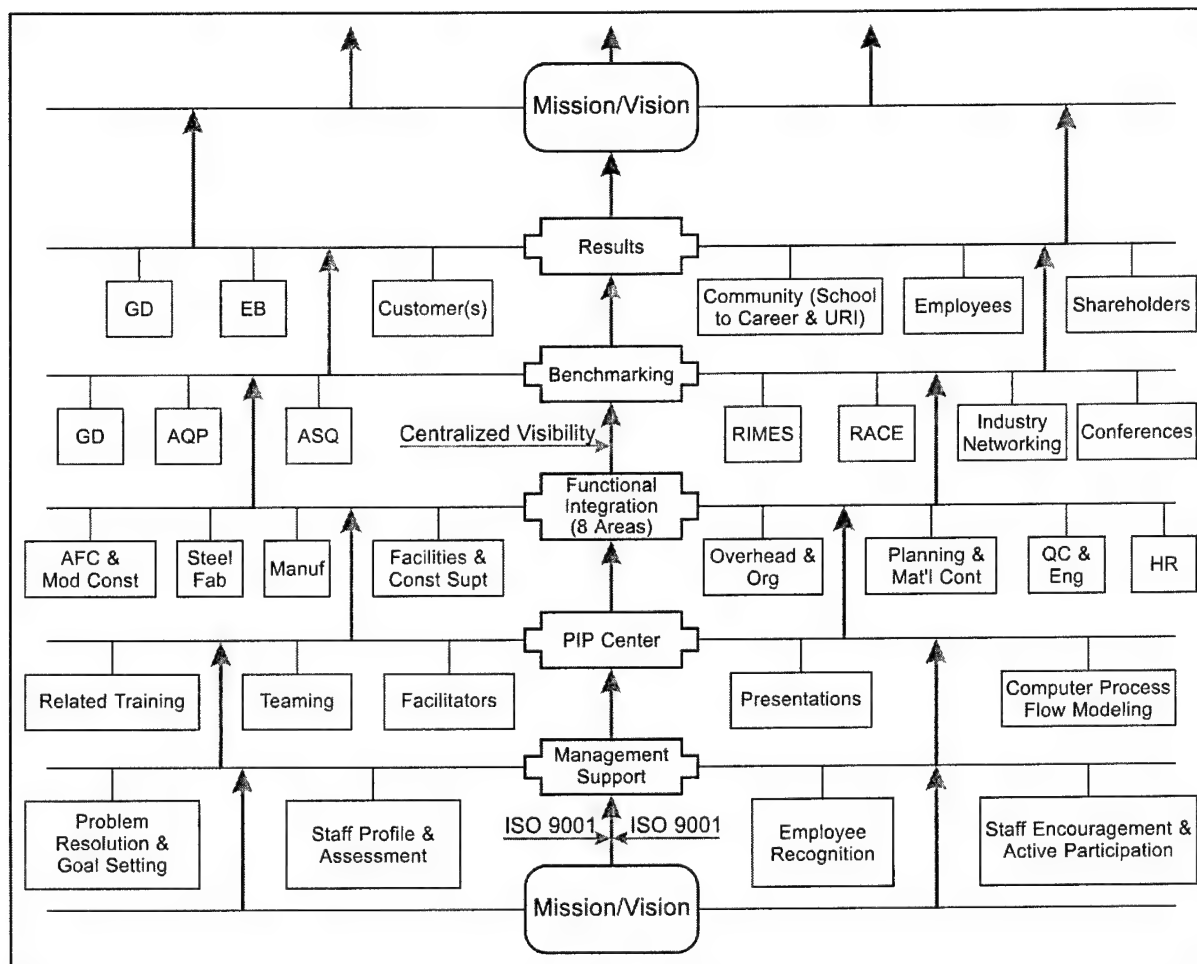


Figure 2-5. Process Improvement Program

The company has revised this objective and hopes to attain an employee participation of 80% by January 1, 2000. Another measurement of the program is implemented improvements. In 1998, EBQP accepted 479 process improvements and implemented 271, most of which were process changes for quality and cost. An analysis based on 1998 figures shows that the company saved more than 68,000 hours in overall labor time and over \$360,000 in material costs.

Recognition Programs

Employee recognition is generally depicted as the appreciation and approval of good performance. EBQP, however, considers employee recognition as the fuel of ongoing motivation, and has developed an extensive list of effective programs:

- **Employee Performance Awards** — Supervisors can acknowledge employees' performances by

presenting them with a certificate and a monetary award of \$25 to \$500. In 1998, EBQP handed out 252 awards, totaling \$23,500. As of March 1999, the company presented 135 awards, totaling \$10,125.

- **Employee Breakfasts, Luncheons, and Barbecues** — EBQP celebrates company achievements (e.g., safety performance, rejection rate reduction, audit performance, ISO-9000 accreditation) by holding festive events for its employees.
- **Supervisory Safety Awards** — Supervisors who achieve zero lost-time accidents throughout the year are presented with monetary awards of up to \$200.
- **Salaried Attendance Program** — Salaried employees who achieve a perfect or less than 1% absenteeism in a given year are entered into a raffle. Winners can receive monetary awards of \$500, \$1,000, or \$2,500. EBQP currently has an absenteeism rate of 1.8%.

- **B-Safe BINGO Program** — This program promotes safety performance. All employees receive a bingo card and try to complete a win based on drawn numbers. A number is drawn for every accident-free day (excluding weekends and holidays) at the facility, and posted at the check-in/check-out gates. Winners can receive up to \$600 in prize money and gifts.
- **SPOT Award Program** — This program reinforces good safety practices. Supervisors award employees who initiate an action which improves safety at the facility. Typical actions include reporting a near miss, clearing an area of a potential hazard, improving the safety of a work area, and alerting supervisors to a potentially unsafe situation. As a reward, the employee receives a coupon that is redeemable for small items such as coffee, lemonade, donuts, ice cream cones, and video rentals.
- **Showcase on Safety Tickets** — This popular program promotes accident-free days via a monthly drawing. Winners receive movie tickets to local area theaters.

EBQP designed its recognition programs to be fast, flexible, easily implemented, and applicable to a large portion of the workforce. The programs focus on seven basic characteristics of effective recognition: sincere; fair/consistent; timely; frequent; flexible; appropriate; and specific.

Safety Quality Action Team and Safety Action Reviews

In 1992, EBQP set up the Safety Quality Action Team (SQAT) with a primary charter of looking at safety recognition for the workforce. The team's success in establishing recognition programs prompted EBQP to task SQAT to other safety related issues. SQAT meets at least once a month to identify, discuss, and resolve safety issues throughout the facility. For issues that cannot be resolved at these meetings, the action is assigned to the appropriate employee(s) and is noted in the minutes until resolved. The team consists of at least one hourly employee from each department, a Safety Department representative, and the Site Manager and staff. This multi-level mix of employees provides the group with insights to safety issues on the factory floor.

SQAT was instrumental in establishing many safety policies and upgrades including those involved in eye safety and burn prevention. After reviewing two years worth of data, the team determined that most eye

injuries occurred in conjunction with pneumatic tools. To address this situation, SQAT set up safety policies on the use of goggles and face shields, and recommended a higher grade of stylish, non-fogging, safety glasses with fixed sides. Another major cause of injury was burns. After studying the data, the team determined that most incidents occurred during the summer months and involved injury to the forearm. A follow-up study confirmed these events occurred regardless of whether the job involved hot work. To address these issues, SQAT established a long sleeve policy for non-hot work, and a burn policy matrix with safety equipment list for hot work. As a result of SQAT's efforts, EBQP significantly decreased its eye and burn injury rates.

SQAT operates as a direct link to upper management, thereby expediting necessary resolutions and reinforcing EBQP's commitment to safety. In conjunction with the team's efforts, the Safety Department holds weekly Safety Action Reviews to evaluate injuries that occurred during the previous week. Participants include the Site Manager and staff, as well as the supervisors and department heads of injured employees. Prior to the meeting, an injury fact finding assessment is held with the injured employees, their supervisor and department head, and a Safety Department representative. Here, the group identifies the exact cause of the injury, and initiates immediate and long-term corrective actions. The findings are presented at the Safety Action Review, where management reviews the circumstances and actions, discusses lessons learned from the incident, and disseminates the information throughout the facility.

Since implementing SQAT and the Safety Action Reviews, EBQP has realized many benefits. The company's safety efforts have been instrumental in promoting personal protective equipment improvements, increasing accident prevention communications, and significantly reducing injury rates.

Security Badge System and Clearance Monitoring

National security is an important aspect at EBQP due to the nature of its business. Great care must be taken in classifying and monitoring clearance levels, and in issuing security badges to employees, vendors, and visitors at the facility. In 1989 and again in 1994, EBQP received the Department of Defense's (DOD's) James S. Cogswell Award for outstanding security achievement. Very few facilities have earned this

honor more than once. Recently, the company upgraded its Employee Badge Control System and Monitoring process.

The Employee Badge Control System operates as a stand-alone process with a minimal number of authorized users, and produces badges that are similar to those issued at Electric Boat's Groton facility. To initiate the process, the Security Department enters data (e.g., personal information, unique badge number, social security number, clearance level) along with a digital image of the employee into the system. The badge is then encoded with the data, and displays the employee's picture and clearance level. Encoding allows the badge to be compatible with the Automated Time and Attendance System which records time/attendance and announces facility events, and the Access Control System which provides entrance through unmanned security gates. Both automated systems feature built-in controls which can lock out unauthorized badges and provide electronic data on employee activity.

The Security Department also monitors the clearance levels of employees, vendors, and visitors to ensure that proper levels are maintained and processed. Department heads submit clearance requests along with justification to the Security Department, which processes the application through the Defense Investigation Service Clearance Office. In recent years, this activity has been considerably high because of DOD's emphasis to reduce clearances. A record of all clearances is maintained by the Security Department and audited by DOD during its annual facilities inspection.

EBQP has realized many benefits since upgrading its Employee Badge Control System and Monitoring process. As a result, the company decreased its cost from \$3.97 for the film system to \$1.46 per badge for the digital system, producing a 63% cost savings. The upgraded system also eliminated shelf life on badge supplies; decreased badge processing time; and provides flexibility for introducing changes in the future. Reclassification of employee clearance levels has also reduced the Secret and Company Confidential categories by more than 50%, while allowing EBQP to maintain a flexible workforce.

Simultaneous Machine Shop Operations Program

In February 1998, EBQP implemented a Simultaneous Machine Shop Operations program as a cost-reduction measure for its Machine Shop. Simultaneous operations is defined as two machines engaged concurrently in either an operating/operating mode

or a set-up/operating mode. Previously, employees ran only one machine at a time in the Machine Shop.

The Simultaneous Machine Shop Operations program was initially tested over a 60-day trial period. Once proven to be effective, the program was officially incorporated into EBQP's procedures. As an incentive, a special pay provision (While-Engaged Rate) of an additional \$2 per hour is awarded to employees who run concurrent machines. Although most simultaneous operations at EBQP involve CNC equipment, a CNC/manual or manual/manual combination is possible.

EBQP has realized significant savings since implementing the Simultaneous Machine Shop Operations program. On average, 12% of the overall workload is processed by 63 machinists using this technique. The average time spent is 460 hours per week or approximately 20,000 hours per year. As a result, the company reduced its labor hours by 4.7%, a net savings of about \$80,000.

Van Pool Program

In 1980, EBQP implemented Quonsetrans, a Van Pool program for its employees. The program's objectives were to reduce the workforce's commuting costs and extend the company's potential recruiting area by minimizing the impact of travel. Furthermore as EBQP's workforce grew to more than 5,000, on-site parking was simply not available.

At the height of the program, Quonsetrans served nearly 500 employees; however, the drastic downsizing of the 1990s reduced the program to 126 employees and 15 vans. Electric Boat Corporation administers the program as a non-profit effort with usage fees paid by the ridership, and provides insurance at corporate rates which significantly reduces operational costs. A key to achieving a break-even state was the addition of a five-year, 100,000-mile, extended care package for the vans through a local dealership, which locks in the cost of parts and labor for the useful life of the vans. Prior to this arrangement, the program suffered losses on a regular basis due to unplanned repair and maintenance expenses. The Corporation purchases vans by utilizing the Federal Highway Administration's interest-free loans. These loans are paid off over a 48-month period, during which each van typically accumulates more than 100,000 miles. As a further cost-reducing factor, Federal Tax Law T-21 allows pre-tax dollars to be withheld from an employee's paycheck to pay for van pool fees.

Since the program's debut, more than 15 million miles have been traveled by Quonsetrans vans. More importantly, 77 million miles have been avoided by

non-car pool vehicles, thereby eliminating 100 cars from Rhode Island roads; avoiding one million miles of travel; and saving 61,000 gallons of gasoline each year. The program has also reduced vehicle emissions by 240 tons since 1985. Quonsetrans has proven to be a win-win situation for all involved. Riders save money, reduce stress, and commute to work safely and reliably. EBQP improves morale and employee relations; increases the geographical market for recruitment; and decreases congestion and on-site parking requirements. The State of Rhode Island reduces pollution, conserves fuel, and decreases traffic and wear-and-tear on its roads. EBQP's Van Pool program has a proven track record of accomplishment and serves as a model for others to follow.

Work-In-Process Management

In 1995, EBQP developed the Work-In-Process Management approach for handling its in-process inventory. Previously, all in-process inventory was delivered to a central warehouse. Here, the inventory was kitted, and then the kits were sent to the next points-of-use. By changing the destination points, the company reduced the cost of maintaining inventory.

EBQP employs a relatively lean production system which emphasizes a pull-demand concept as much as possible. Exceptions are those cases where material lead times or other factors, unique to submarine fabrication, require pre-staging. To implement the Work-In-Process Management approach, EBQP modified its MRP II system to ensure that each part's routing sheet clearly displays a destination point-of-use. This information can be changed dynamically, based on real-time workload conditions. The parts are then delivered to a small kitting area at the destination point-of-use, where technicians can access them as needed. In some cases, items are sent directly to the job area. Another modification of the MRP II system allows technicians to access only the material being installed in units on that day, rather than taking the entire kit. This arrangement relieves the trades of material control responsibilities, and tends to reduce the number of lost or damaged components.

The Work-In-Process Management approach enables EBQP to significantly reduce multiple handling of items, resulting in a savings of 14,000 labor-hours per year. By eliminating excessive handling, the company also reduced transportation costs, storage costs, and transportation damage.

Section 3

Information

Production

Automated Tool Inventory Control Tracking System

In the past, EBQP used a manual system to handle consumable items. One employee flagged all low inventory items by using handwritten, three-part requisition cards. Another employee collected data from these cards and wrote up buy orders. The orders were then processed through signature and procurement cycles which further delayed the reorder process. Unique tools were manually issued out to employees on metal chits. Each employee had five chits for tool withdrawal. Reports on delinquent tools, tool repairs, and replenish orders were generated manually. All consumables issued to an employee required an authorization signature by a supervisor who had to determine the needs and qualifications of the employee. In 1986, EBQP improved these tasks by implementing the Automated Tooling Inventory Control Tracking System (ATICTS).

ATICTS is an end-user designed, automated system that tracks and controls consumable items such as welding inserts, wire, and critical tooling. In addition, this off-the-shelf software package has been enhanced and linked to EBQP's Automated Weld Process Selection System, so only qualified, authorized personnel can obtain an item from the system. ATICTS can track usage and maintain inventory levels which are initially set by the system administrator. Other capabilities of the system include linking directly to the Purchasing Department to ensure timely reordering of low inventory items, and generating a wide variety of reports such as vendor history, unit prices, cost data, delinquent tools by an employee, and daily transactions on issues from the tool crib areas.

ATICTS provides EBQP with an accurate, effective way to track and control consumable items. This system provides on-line information to the tool crib as well to the foreman. Future plans call for replacing the present ATICTS with a newer, PC-driven system that will allow departments to control their individual tooling and inventories.

Calibration Program

In 1992, EBQP implemented the Calibration program as a way to ensure that all tools requiring calibration were sent to the Metrology Laboratory on or before their due date. As a result, the company increased customer satisfaction by preventing any out-of-date calibrated tools from being used for process measurement.

The Calibration program is controlled through a PC-based database which provides real-time data entry, retrieval, and reporting. Like most calibration programs, this one uses a monthly recall report along with a monthly overdue report. However, EBQP also implemented a weekly status report to overcome many weaknesses associated with monthly reporting (e.g., mid-month tool calibration dates, lack of tool availability). This status report forecasts calibration requirements for supervisors by identifying tools due in the upcoming week and providing sufficient advance notice for the timely calibration of tools. The weekly calibration requirements are also attached to the weekly Quality Department report which is sent to the Vice President of Operations, Vice President of Quality, Site Manager, as well as all superintendents, department heads, and staff — thereby guaranteeing the highest level of visibility.

Since implementing the Calibration program, EBQP reduced the number of overdue tools for calibration as well as the amount of time that an item is overdue. In the past, tools were often six to eight weeks overdue for calibration. Today, the company reports it is rare for an item to be overdue by more than two weeks. By also providing each department with a weekly snapshot of tools coming due, supervisors can adjust and coordinate their scheduled production around required tool calibrations.

Computer Numerical Control Manufacturing Capabilities

EBQP utilizes a wide variety of manual and state-of-the-art Computer Numerical Control (CNC) machine tools throughout its facility. These tools are used to perform many of the manufacturing processes in the Machine and Sheet Metal Shops.

The Machine Shop features a mix of manual and CNC turning and machining centers with a wide range of capabilities. The Shop's 20 CNC machines can also perform multiple operations (e.g., turning, milling, drilling) on various shapes and sizes of unique and complex components. Parts that once required multiple machines and set-ups are now being completed on a single machine that only uses one set-up. Many of the CNC machines utilize a DNC connection to the off-line programming area, which provides manufacturing data directly into the machine's controller. EBQP is currently evaluating some of its large-capacity manual machines for possible retrofitting of CNC controls in order to provide them with more versatility. A recent addition to the Machine Shop is a Dorries Scharmann CNC, three-axis, vertical turning center with automatic tool-changing capabilities. This machine features a secondary side spindle with live tooling capable to perform milling and drilling operations on the turned part before it is removed from the machine.

The Sheet Metal Shop also uses a blend of manual and CNC machine tools including Magnum 5000 and Centrum 3000 automated punch and plasma machines. These machines are capable of producing parts of up to 3/8 of an inch in thickness. Machining information is downloaded to the machine from the off-line programming area. Complex parts are nested, so as to obtain maximum utilization of material as well as produce parts per the computerized dispatch list's schedule. The tool paths for programming is derived from the part's CAD data file. By manufacturing only the parts on the computerized dispatch list, EBQP greatly reduced the storage and handling of excess material.

Construction Activities Supported by Deckplate Design-Build Teams

Seeking a way to resolve design-production manufacturing issues associated with the Virginia-class submarines, Electric Boat Corporation set up Deckplate Design-Build Teams (DPDBTs). These teams support current and near-term construction activities. As needed, eight full-time representatives from structural and piping engineering, detail planning, quality, and engineering configuration management respond to design problems which are identified by shop fabricators. The average Engineering Report (ER) response time to resolve design-build problems is currently four days, compared to 23 days for the previous submarine class. ERs which impede

construction work are given the highest priority and are tracked daily on an ER dispatch list.

The DPDBT initiative will also be used by NNS for the construction process of ship sections for the Virginia-class submarines. Since EBQP is the Virginia-class design shipyard, NNS' DPDBTs will be used to resolve fabrication issues, as they arise locally, with EBQP designers. Full-time engineering liaison office representatives from EBQP will also be on-site at NNS to quickly assist in resolving design-fabrication issues.

Cut Neat Program in Structural Areas

As more of the shipbuilding industry is moving toward modular construction for ship assembly, focus has shifted to the delivery of accurate, ready-to-install, cost effective piece parts. One of the ways that EBQP is responding to this need is by implementing the Cut Neat program in structural areas. In the past, material was cut by using burning machines with optical tracing servo units and full-size templates. This approach led to inherent accuracy limitations and potential for errors, as well as cost issues related to generating templates. Due to the limited accuracy of piece parts and other tolerance issues related to the assembly process, workers had to create piece parts with excess stock. This method ensured that the part had sufficient stock, but it often meant that workers had to finish burning or grinding the complex weld joints in very cramped areas during assembly.

The Cut Neat program involves procuring and installing accurate and productive DNC plate-burning equipment. Electronic data taken directly from the wire model provides an accurate tool path for the burning gantry. Increased accuracy of piece parts and improved final assembly techniques offered by modular construction also enable workers to burn most parts to exact size. Edge preparation of parts are now done during the steel processing phase, thereby eliminating burning or grinding tasks during assembly.

Since implementing the Cut Neat program, EBQP realized many benefits. This program enabled the company to produce ready-to-install parts, enhance the accuracy of final assemblies, reduce scheduling time and cost, and preassemble increasingly larger modules off-site.

Electrical Component Installation

Electrical component installation of Seawolf-class submarines involves 158 electrical systems and more

than 6,500 components. In the past, electrical component drawings were prepared for each system, and work progress was tracked manually. Major obstacles were the lack of coordination among trades and the difficulty in ensuring that areas would be accessible to workers for installing individual components (e.g., nuclear cabinets, switchboards, controllers, telephone boxes, electrical outlets). Today, installation involves modular construction and most work is completed prior to final assembly.

Prior to installation, EBQP prepares work packages according to geographical location rather than by system. This approach requires an additional set of trade-specific diagrams known as sectional construction drawings. Trade schedules are also prepared and coordinated so that the maximum number of major components can be loaded and the deck is accessible to overhead cranes. Tasks include layout, transfer, machining, drilling/tapping, stud installation, and setting up individual units. Mounting locations for major equipment are designed with optical tooling and drill fixtures, ensuring that equipment will be properly located and leveled. Work process is tracked electronically by using EBQP's Shipyard Weld Status System.

In the past, employees may have needed as many as nine separate trips to the same bulkhead to complete all of the electrical work. Today, the same work is usually completed in one trip. The company estimates an overall cost savings of 25%.

Flexible Workforce

EBQP's structural fabrication workforce consists of two core trades: welders and shipfitters. Those skilled in both trades are considered members of the flexible workforce.

To be eligible for the flexible workforce, tradespeople must be at the top rate of their own trade. Next, they must work 200 hours in the other trade under the observation of a foreman. Typical assignments include a welder who works with a shipfitter to learn how to perform fit-ups, and a shipfitter who works with an electrician to learn how to layout and stud-shoot electrical hangers. The time worked in the second trade is recorded through EBQP's Automated Time and Attendance System. In addition, a database keeps track of which employees are in the flexible workforce as well as the current status of tradespeople working toward completing the 200-hour requirement.

Once the requirements for flexible workforce are fulfilled, the tradesperson moves up one labor grade (approximately a 25¢ per hour increase). By establish-

ing a flexible workforce, EBQP has the ability to pull additional employees from one trade into another whenever changes in the workload occur.

Lift and Handling Crane Program

In the past at EBQP, maintenance personnel controlled and managed cranes based on requirements from the Operations Department. No formalized deficiency reporting system existed, and maintenance and testing records were filed in their respective shops rather than at a centralized location. EBQP also had no interaction with the Groton facility's crane program, conducted few audits, and lacked a crane inspection training program. Cranes received minimal preventive maintenance and engineering technical support was non-existent. Recognizing these deficiencies, EBQP set up a Lift and Handling Crane program as a formalized process to document maintenance procedures for its cranes.

This program led to other initiatives such as a Crane Inspection Training program; an Engineered Managed Program; a Crane Quality Manual; a Repair, Maintenance, and Modification Report program; a Record-keeping and Filing System; and a Quality Assurance Engineering program. In addition, EBQP modified its MRP II system to handle crane preventive maintenance, annual testing, and monthly inspections. The company now tracks crane trend analysis and performance, develops performance goals, and coordinates its program with the Groton facility.

Since implementing the Lift and Handling Crane program, EBQP realized many benefits. The company reduced the downtime of cranes, improved reliability and is in compliance with OSHA, ANSI, and Navy standards, established compatibility with the Groton facility's crane program, and decreased the number of cranes at Quonset Point by 45%.

On-Board Machining

EBQP has developed and applied many processes and procedures for on-board machining of large fabrications (e.g., deck units, hull structures) used in ship construction. In some cases, surface requirements for size, finish, and tolerance can only be done after the units are welded together and machined in place. As a result, on-hull machining becomes a major part of the fabrication process. Although similar to machining processes used in the shop, on-board machining requires a different set of rules and special machine tools to achieve the proper results.

In a shop, the part is usually placed on the machine while the machining operations are being performed. For on-board machining, the machine tool needs to be mounted on the fabrication being machined in such a way that the machining operation can be performed. Small tools typically use magnetic bases, but large ones must be optically aligned to the baseline of the deck and parallel to the lines of the ship. Dimensional requirements are then established from these lines and used to calculate the machining requirements. Once the baseline is established, the large tool can be moved to any area on the deck to produce surfaces that are flat and parallel to the ship's lines.

Many deck foundations require drilling and tapping of holes to match the component being installed on the foundation. Since decks are usually too large to machine in a shop, these operations must be performed on-board the ship. By using drill fixtures which are manufactured in a shop, hole patterns can be accurately drilled to match the component to be mounted. Final boring operations of welded-in components must be performed on-board to ensure that flatness and size requirements are maintained. Although most components are pre-machined in a shop, the final sizing must be performed after all welding operations are completed. The amount of material that must be machined to achieve final sizing is also decreasing as welding procedures and techniques improve, thereby reducing out-of-round distortion caused by welding. In addition, tooling and cutters are improving, and continue to replace conventional tools. Overall, the newer techniques are improving quality while reducing labor costs.

Pipe Shop Process

In the past, piping operations at EBQP were not automated. Material checks, re-orders, and data retrieval per request were all performed manually. Copies of drawings were done by clerks. Pipe layout and bending calculations were performed by shop personnel at the time of bending, and pipe manufacturing status consisted of verifying that the material had been consumed. Recognizing these weaknesses and the high costs associated with a manual process, EBQP implemented an automated Pipe Shop process.

The Pipe Shop process uses electronic systems for generating and managing the status of pipe operations, thereby improving the accuracy of piping geometry and reducing paper processing times. The program is also fully integrated into EBQP's MRP II system for electronic pipe bend requirement data,

material warehouse status, critical pipe joint identification, pipe marking requirements, and order processing. Other capabilities include accurately tracking consumed material, identifying orders in transit, and electronically closing out orders when completed.

Since implementing the Pipe Shop process, EBQP reduced its manufacturing lead time for pipes from six weeks to ten days. As a result, the company diminished the pipe bending scrap rate to essentially zero, and decreased the labor-hours between like items on the first and second Seawolf-class submarines by 16%.

Powder Paint

EBQP extensively uses an electrostatic powder paint process-to-preservation coating on small assemblies (up to 68 pounds) prior to shipboard installation. These assemblies (e.g., pipe and electrical hangers, small equipment foundations, sound dampening tile cover plates) are first degreased and grit blasted to prepare the surface, followed by an electrostatic painting and curing operation (350°F to 400°F). The thermosetting powder, most extensively used, is a urethane type which changes chemically by cross-linking and polymerizing during the curing cycle. The final cured coating will not melt, soften, or outgas even when exposed to elevated temperatures. Coating thickness generally approaches five mils, with two mils being the minimal acceptable thickness.

EBQP has taken advantage of the many economic and environmental benefits associated with electrostatic powder spray coating. Labor and material costs and scheduling times have significantly been reduced. Previously, the company needed three days to complete a three-coat liquid paint cycle with each coating requiring at least eight hours for painting and drying. By using an automated, overhead traveling continuous conveyor, powder spray coating completes the same job in one hour and 45 minutes. This technique omits the mixing and thinning steps, and eliminates the need for multiple paint and drying cycles.

Material costs have been reduced by the high transfer efficiency of powder coatings and the elimination of solvents. By using powder overspray recovery and recycling, EBQP reclaims 95% of the material application and minimizes waste. The electrostatic powder spray coating process also eliminates the need to satisfy Environmental Protection Agency (EPA) and OSHA requirements regarding the handling, employee exposure, recovery, and disposal of all by-products involved with using potentially carcinogenic solvents.

Release to Weld Process

To better utilize its welding workforce, EBQP changed the way it releases sizeable welding jobs to its welders. In the past, welders waited as pieces were fit-up before being turned over to them for welding. As the welders worked, the overall fit-up operations continued which resulted in frequent interruptions in the welding process.

EBQP has been using the Release to Weld process since the mid-1980s. Through this process, sizeable welding jobs are only released to the welders when large sections of a deck assembly or tank are fit-up, tacked, and ready for joining. Since the fit-up on these sections is complete, the welder can begin work immediately and continue uninterrupted for days or weeks depending on the job size.

Since implementing the Release to Weld process, EBQP improved weld deposition rates, increased arc times, and reduced scheduling. The company estimates the process has resulted in a cost savings of up to 10% for deck assemblies and about 15% to 20% for tanks.

Ultrasonic and Radiography Welding Program

During the construction of submarine subassemblies at EBQP, numerous structural weld joints require ultrasonic and radiographic testing (UT/RT) to confirm specification-required acceptance weld quality. The company uses a team of structural welders known as the Ultrasonic and Radiography Team to maintain the high degree of quality for these critical welds. As each weld is completed and inspected, the nondestructive test results are loaded into an electronic database. Using this information, the company can track the weld quality performance for each welder. The database also assists supervisors in selecting a welder with appropriate skill levels for a job. This approach has worked extremely well at EBQP as quality performance data shows a rejection rate of less than 1% for all UT/RT structural welds.

Improvements in structural weld quality began in 1990 when EBQP set up a Quality Action Team (QAT) to take responsibility for weld quality in support of UT/RT requirements. QAT consisted of a senior

structural manufacturing engineer, a welding foreman, a welding engineer, and UT/RT welders. The team initially met on a weekly basis and established a monthly report on performance trends by welder, process, and orientation. This format permitted the selection of welders based on demonstrated performance of shipyard welding processes and orientation of the weld joint. All UT/RT-rejected weld joints initiate a fact-finding effort by the welding foreman and the responsible welder to identify the cause of the defect and determine appropriate corrective actions.

Through the efforts of QAT, EBQP significantly reduced its UT/RT reject rate. Figure 3-1 shows a plot of structural, UT-inspected weld performance at EBQP between 1991 and 1998. In 1998, only 79.4 inches out of 20,565.5 inches of UT-inspected welds were rejected, representing a remarkable rejection rate of only 0.4%. EBQP also recognizes its UT/RT welders' accomplishments at an annual luncheon where certificates and jackets are awarded. Embroidery on the jacket identifies the wearer as a UT/RT quality welder.

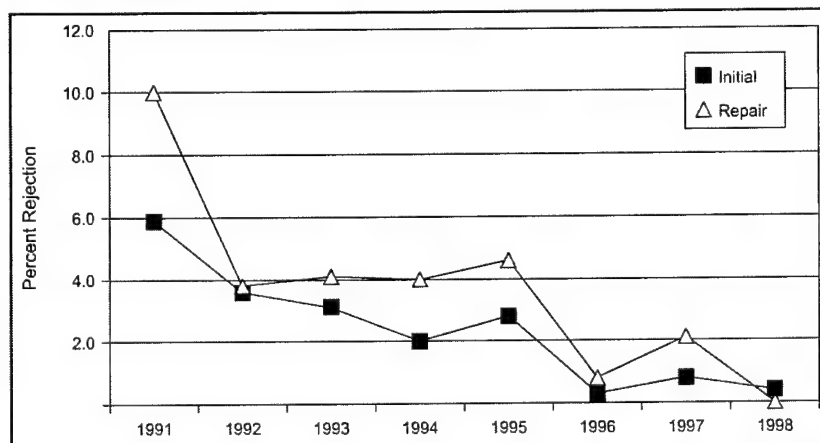


Figure 3-1. Structural Ultrasonic Weld Performance

Welding Procedures and Processes

EBQP uses a wide range of welding procedures (e.g., gas tungsten arc, shielded metal arc, gas metal arc, submerged arc, stud, flux cored arc); methods (e.g., manual, semi-automatic, mechanized, automatic, robotic); and base materials (e.g., aluminum, titanium, high yield steels, corrosion resistant steels, copper and bronze alloys, high nickel alloys) to meet its production requirements. The large number of processes and materials requires almost 1,000 different welding technique sheets and procedures. To determine which of its

229 structural and 54 pipe welders are certified for a particular job, supervisors use EBQP's Automated Welder Process Selection System.

Other welding improvements include the Automated Frame and Cylinder Facility, and a Programmable Automated Welding System (PAWS). The latter is a welding gantry with two robotic arms which are controlled by an off-line programming system. PAWS accepts downloaded CAD models to a proprietary software which creates welding parameters and a weld path. Physically, the cell has a work envelope of six feet in height and 42 feet in width, and is only limited in length by the utility connections. PAWS employs three types of sensors (laser, touch, and through-the-arc) for path guidance.

EBQP's ability and willingness to adapt to an increasingly complex set of weld requirements have proven to be beneficial in meeting production requirements. As a result, customers receive more products at a higher quality.

Facilities

Environmental Resources Management

EBQP is proactive in all aspects of environmental resource management. All employees receive pollution prevention training with the overall message of *Environmental Management Is Everyone's Responsibility*. In that regard, the company is satisfying existing compliance requirements and addressing potential long-term liability issues.

The company's efforts in pollution abatement include the following:

- The Quonset Point site has been cleared of polychlorinated biphenyl-containing electrical transformers since 1989.
- All underground fuel tanks (e.g., gasoline, diesel) have been removed, and the surrounding soil has been certified as free of contaminants. Current fuel storage consists of above ground, easily monitored tanks.
- All recyclable materials are collected, separated, and delivered to local recyclers. Recycled materials include paper, cardboard, oil, wood, ferrous and non-ferrous metals, and lead acid batteries.
- EBQP extensively uses an electrostatic powder paint spray coating on small structural steel items (up to 68 pounds), followed by an elevated temperature cure cycle. This process and the use of low volatile organic compound liquid paints and

aqueous cleaners for degreasing parts contribute to the company's efforts to being an EPA and OSHA compliant manufacturing facility.

Management

Complaint Procedure and Open Door Policy

EBQP developed two alternative processes for resolving workplace issues: the Complaint Procedure and the Open Door Policy. Each process supports the company's philosophy of an open dialogue between employees and management within an environment of cooperation and respect in the workplace. Employees may utilize one process or the other, but not both. In most cases, complaints are resolved informally through open communication without rising to the level of a formal complaint.

The Complaint Procedure is a formal policy for resolving complaints. Each step is governed by a specific procedure that allows the employee to take a complaint to a review board. Each department has an Employee Relations Representative to assist with either the Complaint Procedure or the Open Door Policy. A complaint is defined as anything that occurs at work which an employee believes to be unjust, wrong, or unfair *and* contradicts company policy. To file a complaint, employees notify their supervisor or file a complaint through the Human Resources Office. Attempts are made to resolve the complaint at the first level whenever possible. The employee's supervisor is notified within five days and has two days to respond. If the response is unacceptable, the department head is notified within five days and has three days to respond. Failing resolution, the issue will be heard by a review board within five days. The review board must render a decision in three working days from the hearing. The review board consists of two members of management and two hourly employees, all selected by lottery. The Human Resources manager or designee serves as chairperson, whose role is to provide guidance, direction, and ensure consistency, and is a non-voting member of the board. If the board is evenly decided, the complaint will go to the Site Manager who must give a decision within ten days. The decision of the Site Manager is final. In 1998, 12 formal complaints were filed. Of these, three went to the review board while the others were resolved at the department head level.

The Open Door Policy is an informal process, designed to address complaints that are outside the scope of the Complaint Procedure. Although there are no set time frames for resolution, it must be done within a reasonable period of time. The complaint can go to any level of management at any time, but employees are encouraged to follow the chain of command if possible. Employees who choose this method receive assistance from the Human Resources Office throughout all levels of the process. Again, the Site Manager has the final say in resolving the issue. In 1998, approximately 20 complaints were resolved using the Open Door Policy.

These two processes have been very effective in ensuring open communications and resolving complaints promptly and fairly. EBQP has a strict no retaliation policy in effect to ensure no employee's job can be jeopardized by choosing a method of resolution. The relatively small number of formal complaints for an organization of this size is an indication that the open communication environment has been achieved throughout all levels of the company.

Computer-Based Training

Based on a long recognized need to make refresher training available to shop floor and office personnel, EBQP is currently implementing two computer-based learning tools. One involves CD-ROM technology and the other uses web-based technology.

The first is a demonstration tool that utilizes an internally produced CD-ROM. Employees will be able to access the training program either by using a personal computer at a foreman's workstation or via the company's Internet system. The CD-ROM will feature a short tutorial on navigating the tool, and will demonstrate shop floor techniques to the user by

displaying a combination of audio, video, text, and still photographs. Users will encounter frequent short quizzes which ensure that they have understood the information. Afterwards, employees will also be required to take an interactive exam to demonstrate that they have mastered the material.

The second tool is a commercially available, web-based teaching library developed by Knowledge Communications. The library consists of management courses that may be changed periodically. Currently, EBQP has a three-year contract with the supplier which will permit up to 1,000 Internet users to access ten teaching programs in the library.

Critical Skills Database

EBQP has developed a Critical Skills Database which will be implemented on October 1, 1999. The database will identify and track critical skills, as required by the different trades for nuclear and non-nuclear applications, and list which employees have been trained in these skills.

Using Microsoft's Excel spreadsheets, the Critical Skills Database will link the training information to EBQP's Training Records System. The spreadsheets will list all relevant training information for each employee including courses taken and certification/renewal dates for the different trades. This system will replace the previous method which involved contacting the Human Resources Office for information. Although this paper-based method was updated weekly, the information was not always current.

By using the Critical Skills Database, supervisors will be able to access real-time information on employees and determine who has been certified in a particular critical skill. The database will also include information on employees' vision tests.

Appendix A

Table of Acronyms

Acronym	Definition
AFC	Automated Frame and Cylinder
AT&A	Automated Time and Attendance
ATICTS	Automated Tooling Inventory Control Tracking System
AWPSS	Automated Weld Process Selection System
CAD	Computer Aided Design
CNC	Computer Numerical Control
DNC	Direct Numerical Control
DOD	Department of Defense
DPDBT	Deckplate Design-Build Team
EBQP	Electric Boat Corporation, Quonset Point Facility
ECSA	Employee Community Services Association
EMS	Energy Management System
EPA	Environmental Protection Agency
ER	Engineering Report
EVS	Electronic Visualization Simulation
HVAC	Heating, Ventilation, and Air Conditioning
MRP	Manufacturing Resources Planning
NDT	Non-Destructive Testing
NNS	Newport News Shipbuilding
NPS	National Pipe Standard
OSHA	Occupational Safety and Health Administration
PAWS	Programmable Automated Welding System
PIP	Process Improvement Program
PPE	Personal Protective Equipment
QAT	Quality Action Team
RT	Radiographic Testing
SQAT	Safety Quality Action Team
SWSS	Shipyard Weld Status System
UT	Ultrasonic Testing

Appendix B

BMP Survey Team

Team Member	Activity	Function
Robert Jenkins (703) 602-3003	Naval Sea Systems Command Arlington, VA	Team Chairman
Cheri Spencer (301) 403-8100	BMP Center of Excellence College Park, MD	Technical Writer

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John Bissell (703) 602-5386 x154	Naval Sea Systems Command Arlington, VA	Team Leader
Ray Juers (301) 227-5075	Naval Surface Warfare Center Carderock, MD	
John Carney (703) 696-0352	Office of Naval Research Arlington, VA	

Production Team 2

Larry Robertson (812) 854-5336	Naval Surface Warfare Center Crane, IN	Team Leader
Jack Tamargo (707) 642-4267	BMP Satellite Center Vallejo, CA	
Mike Allen (423) 574-3468	Lockheed Martin Energy Systems Oak Ridge, TN	

Management Team 1

Larry Halbig (317) 891-9901	BMP Field Office Indianapolis, IN	Team Leader
Jack McInnis (703) 271-9055	Production Technology, Inc. Arlington, VA	
John Olewnik (215) 697-9526	Office of Naval Research Manufacturing Technology Detachment Philadelphia, PA	

Management Team 2

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BMP Center of Excellence
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Team Leader

Leo Plonsky
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Office of Naval Research
Manufacturing Technology Detachment
Philadelphia, PA

Sarah Mitchell
(703) 271-9055

Production Technology, Inc.
Arlington, VA

Appendix C

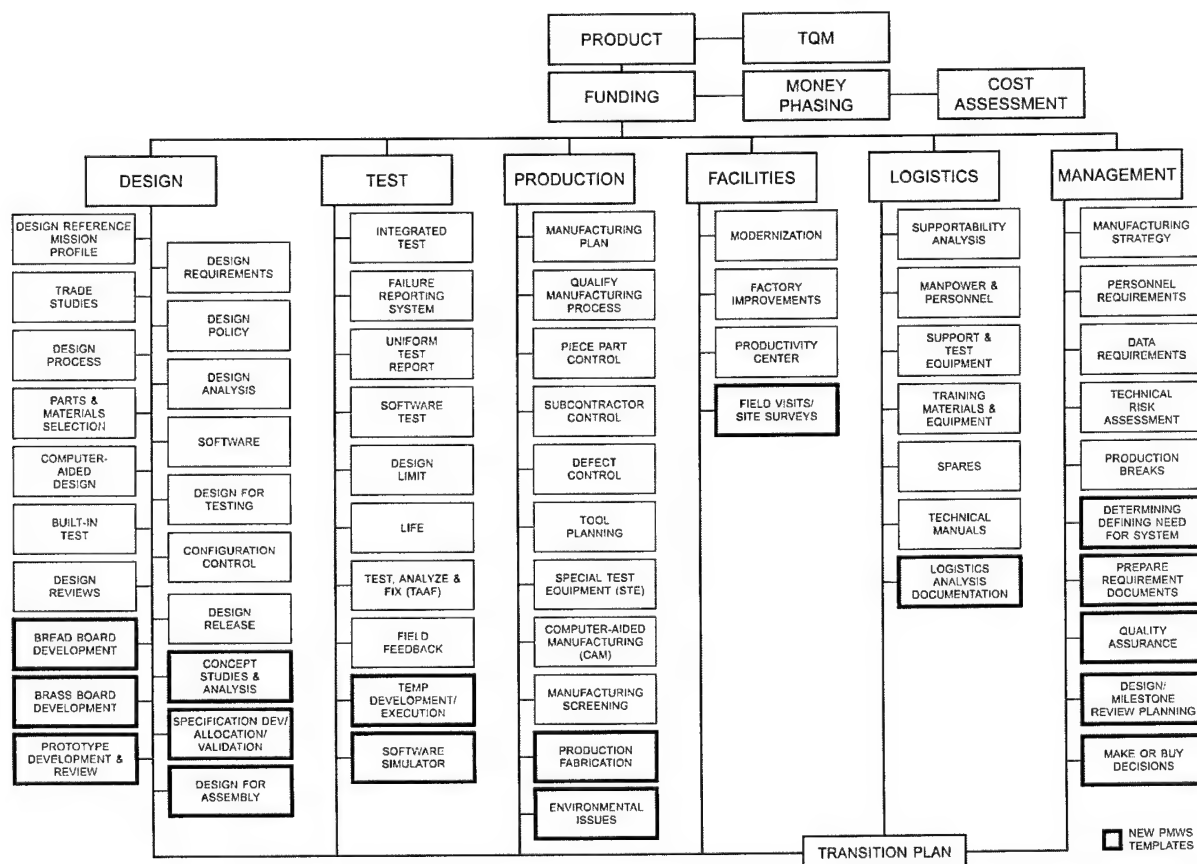
Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, *Transition from Development to Production* document. This publication defines the proper tools—or templates—that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition

process by addressing it as an *industrial* process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

“CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION”



Appendix D

BMPnet and the Program Manager's WorkStation

The BMPnet, located at the Best Manufacturing Practices Center of Excellence (BMPCOE) in College Park, Maryland, supports several communication features. These features include the Program Manager's WorkStation (**PMWS**), electronic mail and file transfer capabilities, as well as access to Special Interest Groups (SIGs) for specific topic information and communication. The BMPnet can be accessed through the World Wide Web (at <http://www.bmpcoe.org>), through free software that connects directly over the Internet or through a modem. The PMWS software is also available on CD-ROM.

PMWS provides users with timely acquisition and engineering information through a series of interrelated software environments and knowledge-based packages. The main components of PMWS are KnowHow, SpecRite, the Technical Risk Identification and Mitigation System (TRIMS), and the BMP Database.

KnowHow is an intelligent, automated program that provides rapid access to information through an intelligent search capability. Information currently available in KnowHow handbooks includes Acquisition Streamlining, Non-Development Items, Value Engineering, NAVSO P-6071 (Best Practices Manual), MIL-STD-2167/2168 and the DoD 5000 series documents. KnowHow cuts document search time by 95%, providing critical, user-specific information in under three minutes.

SpecRite is a performance specification generator based on expert knowledge from all uniformed services. This program guides acquisition person-

nel in creating specifications for their requirements, and is structured for the build/approval process. SpecRite's knowledge-based guidance and assistance structure is modular, flexible, and provides output in MIL-STD 961D format in the form of editable WordPerfect® files.

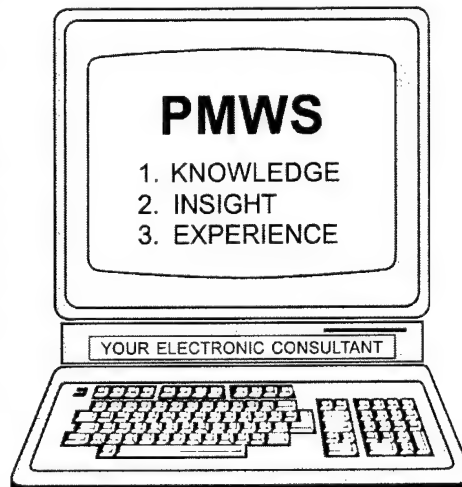
TRIMS, based on DoD 4245.7-M (the transition templates), NAVSO P-6071, and DoD 5000 event-oriented acquisition, helps the user identify and rank a program's high-risk areas. By helping the user conduct a full range of risk assessments through-

out the acquisition process, TRIMS highlights areas where corrective action can be initiated before risks develop into problems. It also helps users track key project documentation from concept through production including goals, responsible personnel, and next action dates for future activities.

The **BMP Database** contains proven best practices from industry, government, and the academic communities. These best practices are in the areas of design, test, production, facilities, management, and logistics. Each practice has been

observed, verified, and documented by a team of government experts during BMP surveys.

Access to the BMPnet through dial-in or on Internet requires a special modem program. This program can be obtained by calling the BMPnet Help Desk at (301) 403-8179 or it can be downloaded from the World Wide Web at <http://www.bmpcoe.org>. To receive a user/e-mail account on the BMPnet, send a request to helpdesk@bmpcoe.org.



Appendix E

Best Manufacturing Practices Satellite Centers

There are currently ten Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; and train regional personnel in the use of BMP resources such as the BMPnet.

The ten BMP satellite centers include:

California

Chris Matzke

BMP Satellite Center Manager
Naval Warfare Assessment Division
Code QA-21, P.O. Box 5000
Corona, CA 91718-5000
(909) 273-4992
FAX: (909) 273-4123
cmatzke@bmpcoe.org

Jack Tamargo

BMP Satellite Center Manager
257 Cottonwood Drive
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FAX: (707) 642-4267
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District of Columbia

Chris Weller

BMP Satellite Center Manager
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FAX: (202) 482-5650
cweller@bxa.doc.gov

Illinois

Thomas Clark

BMP Satellite Center Manager
Rock Valley College
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(815) 654-5515
FAX: (815) 654-4459
adme3tc@rvcux1.rvc.cc.il.us

Iowa

Bruce Coney

Program Manager
Iowa Procurement Outreach Center
200 East Grand Avenue
Des Moines, IA 50309
(515) 242-4888
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bruce.coney@ided.state.ia.us

Louisiana

Al Knecht

Director
Maritime Environmental Resources & Information
Center
Gulf Coast Region Maritime Technology Center
University of New Orleans
810 Engineering Building
New Orleans, LA 70148
(504) 626-8918 / (504) 280-6271
FAX: (504) 727-4121
atk@neosoft.com

Michigan

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SAE/BMP Satellite Center Manager
755 W. Big Beaver Road, Suite 1600
Troy, MI 48084
(248) 273-2460
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Oak Ridge, TN 37831-8091
(423) 576-5532
FAX: (423) 574-2000
tgraham@bmpcoe.org

Appendix F

Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Sciences and Technology Program established the following Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and Navy centers and laboratories. These COEs are consortium-structured for industry, academia, and government involvement in developing and implementing technologies. Each COE has a designated point of contact listed below with the individual COE information.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and promote exemplary manufacturing and business practices and to disseminate this information to the U.S. Industrial Base. The BMPCOE was established by the Navy's BMP program, Department of Commerce's National Institute of Standards and Technology, and the University of Maryland at College Park, Maryland. The BMPCOE improves the use of existing technology, promotes the introduction of improved technologies, and provides non-competitive means to address common problems, and has become a significant factor in countering foreign competition.

Point of Contact:
Mr. Ernie Renner
Best Manufacturing Practices Center of Excellence
4321 Hartwick Road
Suite 400
College Park, MD 20740
(301) 403-8100
FAX: (301) 403-8180
ernie@bmpcoe.org

Center of Excellence for Composites Manufacturing Technology

The Center of Excellence for Composites Manufacturing Technology (CECMT) provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors. The CECMT is managed by the Great Lakes Composites Consortium and represents a collaborative effort among industry, academia, and government to develop, evaluate, demonstrate, and test composites manufacturing technologies. The technical work is problem-driven to reflect current and future Navy needs in the composites industrial community.

Point of Contact:
Mr. James Ray
Center of Excellence for Composites Manufacturing Technology
c/o GLCC, Inc.
103 Trade Zone Drive
Suite 26C
West Columbia, SC 29170
(803) 822-3708
FAX: (803) 822-3710
jrglcc@glcc.org

Electronics Manufacturing Productivity Facility

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of industry, university, and government participants, led by the American Competitiveness Institute under a CRADA with the Navy.

Point of Contact:
Mr. Alan Criswell
Electronics Manufacturing Productivity Facility
One International Plaza
Suite 600
Philadelphia, PA 19113
(610) 362-1200
FAX: (610) 362-1290
criswell@aci-corp.org

National Center for Excellence in Metalworking Technology

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. The NCEMT, operated by Concurrent Technologies Corporation, helps the

Navy and defense contractors improve manufacturing productivity and part reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:
Mr. Richard Henry
National Center for Excellence in Metalworking
Technology
c/o Concurrent Technologies Corporation
100 CTC Drive
Johnstown, PA 15904-3374
(814) 269-2532
FAX: (814) 269-2501
henry@ctc.com

Navy Joining Center

The Navy Joining Center (NJC) is operated by the Edison Welding Institute and provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues.

Point of Contact:
Mr. David P. Edmonds
Navy Joining Center
1250 Arthur E. Adams Drive
Columbus, OH 43221-3585
(614) 688-5096
FAX: (614) 688-5001
dave_edmonds@ewi.org

Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality, and safe energetics. The focus of the EMTC is on process

technology with a goal of reducing manufacturing costs while improving product quality and reliability. The EMTC also maintains a goal of development and implementation of environmentally benign energetics manufacturing processes.

Point of Contact:
Mr. John Brough
Energetics Manufacturing Technology Center
Indian Head Division
Naval Surface Warfare Center
101 Strauss Avenue
Building D326, Room 227
Indian Head, MD 20640-5035
(301) 744-4417
DSN: 354-4417
FAX: (301) 744-4187
mt@command.ih.navy.mil

Institute for Manufacturing and Sustainment Technologies

The Institute for Manufacturing and Sustainment Technologies (iMAST), was formerly known as Manufacturing Science and Advanced Materials Processing Institute. Located at the Pennsylvania State University's Applied Research Laboratory, the primary objective of iMAST is to address challenges relative to Navy and Marine Corps weapon system platforms in the areas of mechanical drive transmission technologies, materials science technologies, high energy processing technologies, and repair technology.

Point of Contact:
Mr. Henry Watson
Institute for Manufacturing and Sustainment
Technologies
ARL Penn State
P.O. Box 30
State College, PA 16804-0030
(814) 865-6345
FAX: (814) 863-1183
hew2@psu.edu

National Network for Electro-Optics Manufacturing Technology

The National Network for Electro-Optics Manufacturing Technology (NNEOMT), a low overhead virtual organization, is a national consortium of electro-optics industrial companies, universities, and government research centers that share their electro-optics expertise and capabilities through project teams focused on Navy requirements. NNEOMT is managed by the Ben Franklin Technology Center of Western Pennsylvania.

Point of Contact:
Dr. Raymond V. Wick
National Network for Electro-Optics Manufacturing
Technology
One Parks Bend
Box 24, Suite 206
Vandergrift, PA 15690
(724) 845-1138
FAX: (724) 845-2448
wick@nneomt.org

Gulf Coast Region Maritime Technology Center

The Gulf Coast Region Maritime Technology Center (GCRMTC) is located at the University of New Orleans and focuses primarily on product developments in support of the U.S. shipbuilding industry. A sister site at Lamar University in Orange, Texas focuses on process improvements.

Point of Contact:
Dr. John Crisp, P.E.
Gulf Coast Region Maritime Technology Center
University of New Orleans
College of Engineering
Room EN-212
New Orleans, LA 70148
(504) 280-5586
FAX: (504) 280-3898
jncme@uno.edu

Manufacturing Technology Transfer Center

The focus of the Manufacturing Technology Transfer Center (MTTC) is to implement and integrate defense and commercial technologies and develop a technical assistance network to support the Dual Use Applications Program. MTTC is operated by Innovative Productivity, Inc., in partnership with industry, government, and academia.

Point of Contact:
Mr. Raymond Zavada
Manufacturing Technology Transfer Center
119 Rochester Drive
Louisville, KY 40214-2684
(502) 452-1131
FAX: (502) 451-9665
rzavada@mttc.org

Appendix G

Completed Surveys

As of this publication, 115 surveys have been conducted and published by BMP at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPnet. Requests for copies of recent survey reports or inquiries regarding the BMPnet may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 400
College Park, MD 20740
Attn: Mr. Ernie Renner, Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
ernie@bmpcoe.org

1985	Litton Guidance & Control Systems Division - Woodland Hills, CA
1986	Honeywell, Incorporated Undersea Systems Division - Hopkins, MN (Alliant TechSystems, Inc.) Texas Instruments Defense Systems & Electronics Group - Lewisville, TX General Dynamics Pomona Division - Pomona, CA Harris Corporation Government Support Systems Division - Syosset, NY IBM Corporation Federal Systems Division - Owego, NY Control Data Corporation Government Systems Division - Minneapolis, MN
1987	Hughes Aircraft Company Radar Systems Group - Los Angeles, CA ITT Avionics Division - Clifton, NJ Rockwell International Corporation Collins Defense Communications - Cedar Rapids, IA UNISYS Computer Systems Division - St. Paul, MN (Paramax)
1988	Motorola Government Electronics Group - Scottsdale, AZ General Dynamics Fort Worth Division - Fort Worth, TX Texas Instruments Defense Systems & Electronics Group - Dallas, TX Hughes Aircraft Company Missile Systems Group - Tucson, AZ Bell Helicopter Textron, Inc. - Fort Worth, TX Litton Data Systems Division - Van Nuys, CA GTE C ³ Systems Sector - Needham Heights, MA
1989	McDonnell-Douglas Corporation McDonnell Aircraft Company - St. Louis, MO Northrop Corporation Aircraft Division - Hawthorne, CA Litton Applied Technology Division - San Jose, CA Litton Amecom Division - College Park, MD Standard Industries - LaMirada, CA Engineered Circuit Research, Incorporated - Milpitas, CA Teledyne Industries Incorporated Electronics Division - Newbury Park, CA Lockheed Aeronautical Systems Company - Marietta, GA Lockheed Corporation Missile Systems Division - Sunnyvale, CA Westinghouse Electronic Systems Group - Baltimore, MD General Electric Naval & Drive Turbine Systems - Fitchburg, MA Rockwell International Corporation Autonetics Electronics Systems - Anaheim, CA TRICOR Systems, Incorporated - Elgin, IL
1990	Hughes Aircraft Company Ground Systems Group - Fullerton, CA TRW Military Electronics and Avionics Division - San Diego, CA MechTronics of Arizona, Inc. - Phoenix, AZ Boeing Aerospace & Electronics - Corinth, TX Technology Matrix Consortium - Traverse City, MI Textron Lycoming - Stratford, CT

1991	<i>Resurvey of Litton Guidance & Control Systems Division</i> - Woodland Hills, CA Norden Systems, Inc. - Norwalk, CT Naval Avionics Center - Indianapolis, IN United Electric Controls - Watertown, MA Kurt Manufacturing Co. - Minneapolis, MN MagneTek Defense Systems - Anaheim, CA Raytheon Missile Systems Division - Andover, MA AT&T Federal Systems Advanced Technologies and AT&T Bell Laboratories - Greensboro, NC and Whippany, NJ <i>Resurvey of Texas Instruments Defense Systems & Electronics Group</i> - Lewisville, TX
1992	Tandem Computers - Cupertino, CA Charleston Naval Shipyard - Charleston, SC Conax Florida Corporation - St. Petersburg, FL Texas Instruments Semiconductor Group Military Products - Midland, TX Hewlett-Packard Palo Alto Fabrication Center - Palo Alto, CA Watervliet U.S. Army Arsenal - Watervliet, NY Digital Equipment Company Enclosures Business - Westfield, MA and Maynard, MA Computing Devices International - Minneapolis, MN <i>(Resurvey of Control Data Corporation Government Systems Division)</i> Naval Aviation Depot Naval Air Station - Pensacola, FL
1993	NASA Marshall Space Flight Center - Huntsville, AL Naval Aviation Depot Naval Air Station - Jacksonville, FL Department of Energy Oak Ridge Facilities (Operated by Martin Marietta Energy Systems, Inc.) - Oak Ridge, TN McDonnell Douglas Aerospace - Huntington Beach, CA Crane Division Naval Surface Warfare Center - Crane, IN and Louisville, KY Philadelphia Naval Shipyard - Philadelphia, PA R. J. Reynolds Tobacco Company - Winston-Salem, NC Crystal Gateway Marriott Hotel - Arlington, VA Hamilton Standard Electronic Manufacturing Facility - Farmington, CT Alpha Industries, Inc. - Methuen, MA
1994	Harris Semiconductor - Melbourne, FL United Defense, L.P. Ground Systems Division - San Jose, CA Naval Undersea Warfare Center Division Keyport - Keyport, WA Mason & Hanger - Silas Mason Co., Inc. - Middletown, IA Kaiser Electronics - San Jose, CA U.S. Army Combat Systems Test Activity - Aberdeen, MD Stafford County Public Schools - Stafford County, VA
1995	Sandia National Laboratories - Albuquerque, NM Rockwell Defense Electronics Collins Avionics & Communications Division - Cedar Rapids, IA <i>(Resurvey of Rockwell International Corporation Collins Defense Communications)</i> Lockheed Martin Electronics & Missiles - Orlando, FL McDonnell Douglas Aerospace (St. Louis) - St. Louis, MO <i>(Resurvey of McDonnell-Douglas Corporation McDonnell Aircraft Company)</i> Dayton Parts, Inc. - Harrisburg, PA Wainwright Industries - St. Peters, MO Lockheed Martin Tactical Aircraft Systems - Fort Worth, TX <i>(Resurvey of General Dynamics Fort Worth Division)</i> Lockheed Martin Government Electronic Systems - Moorestown, NJ Sacramento Manufacturing and Services Division - Sacramento, CA JLG Industries, Inc. - McConnellsburg, PA
1996	City of Chattanooga - Chattanooga, TN Mason & Hanger Corporation - Pantex Plant - Amarillo, TX Nascote Industries, Inc. - Nashville, IL Weirton Steel Corporation - Weirton, WV NASA Kennedy Space Center - Cape Canaveral, FL Department of Energy, Oak Ridge Operations - Oak Ridge, TN

1997

Headquarters, U.S. Army Industrial Operations Command - Rock Island, IL
SAE International and Performance Review Institute - Warrendale, PA
Polaroid Corporation - Waltham, MA
Cincinnati Milacron, Inc. - Cincinnati, OH
Lawrence Livermore National Laboratory - Livermore, CA
Sharretts Plating Company, Inc. - Emigsville, PA
Thermacore, Inc. - Lancaster, PA
Rock Island Arsenal - Rock Island, IL
Northrop Grumman Corporation - El Segundo, CA
(Resurvey of Northrop Corporation Aircraft Division)
Letterkenny Army Depot - Chambersburg, PA
Elizabethtown College - Elizabethtown, PA
Tooele Army Depot - Tooele, UT

1998

United Electric Controls - Watertown, MA
Strite Industries Limited - Cambridge, Ontario, Canada
Northrop Grumman Corporation - El Segundo, CA
Corpus Christi Army Depot - Corpus Christi, TX
Anniston Army Depot - Anniston, AL
Naval Air Warfare Center, Lakehurst - Lakehurst, NJ
Sierra Army Depot - Herlong, CA
ITT Industries Aerospace/Communications Division - Fort Wayne, IN
Raytheon Missile Systems Company - Tucson, AZ
Naval Aviation Depot North Island - San Diego, CA
U.S.S. Carl Vinson (CVN-70) - Commander Naval Air Force, U.S. Pacific Fleet
Tobyhanna Army Depot - Tobyhanna, PA

1999

Wilton Armetale - Mount Joy, PA
Applied Research Laboratory, Pennsylvania State University - State College, PA
Electric Boat Corporation, Quonset Point Facility - North Kingstown, RI
